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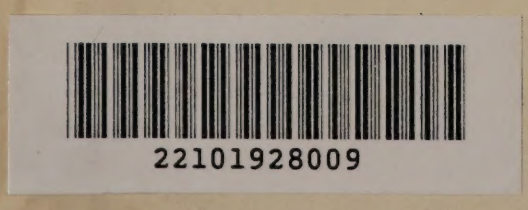
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ROYAL COMMISSION ON SEWAGE DISPOSAL.

FIFTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

METHODS OF TREATING AND DISPOSING OF SEWAGE.

REPORT.

Presented to both Houses of Parliament by Command of His Majesty.



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VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath; Our Trusty and Well-beloved Sir Richard Thorne Thorne, Knight Commander of Our Most Honourable Order of the Bath, Medical Officer of the Local Government Board; Our Trusty and Well-beloved Constantine Phipps Carey, Esquire, Lieutenant-Colonel and Honorary Major-General on the Retired List of Our Army; Our Trusty and Well-beloved Charles Philip Cotton, Esquire; Our Trusty and Well-beloved Michael Foster, Esquire, Master of Arts, Professor of Physiology in Our University of Cambridge; Our Trusty and Well-beloved Thomas Walter Harding, Esquire, Retired Lieutenant-Colonel of Our Auxiliary Forces, with Honorary Rank of Colonel; Our Trusty and Well-beloved Thomas William Killick, Esquire; Our Trusty and Well-beloved William Ramsay, Esquire, Professor of Chemistry, University College, London; and Our Trusty and Well-beloved James Burn Russell, Esquire, Doctor of Medicine, Master of Surgery: Greeting!

Whereas We have deemed it expedient that a Commission should forthwith issue to inquire and report:

1. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory, or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities; and

   (2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage;

Now know ye, that We, reposing great trust and confidence in your knowledge and ability, have authorised and appointed, and do by these Presents authorise and appoint, you, the said Walter Stafford, Earl of Iddesleigh, Sir Richard Thorne Thorne, Constantine Phipps Carey, Charles Philip Cotton, Michael Foster, Thomas Walter Harding, Thomas William Killick, William Ramsay, and James Burn Russell to be Our Commissioners for the purposes of the said Inquiry.

And, for the better effecting the purposes of this, Our Commission, We do by these Presents give and grant unto you, or any three or more of you, full power to call before you such persons as you shall judge likely to afford you any information upon the subject of this Our Commission; and also to call for, have access to, and examine all such books, documents, registers, and records as may afford you the fullest information on the subject, and to inquire of and concerning the premises by all other lawful ways and means whatsoever.

And We do by these Presents authorise and empower you, or any three or more of you, to visit and personally inspect such places as you may deem it expedient so to inspect for the more effectual carrying out of the purposes aforesaid.

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And We do further by these Presents will and ordain that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, and of every matter and thing therein contained, although the same be not continued from time to time by adjournment.

And We do further ordain that you, or any three or more of you, have liberty to report your proceedings under this Our Commission from time to time, if you shall judge it expedient so to do.

And Our further Will and Pleasure is that you do, with as little delay as possible, report to Us, under your hands and seals, or under the hands and seals of any three or more of you, your opinion upon the matters herein submitted for your consideration.

And for the purpose of aiding you in such matters, We hereby appoint Our Trusty and Well-beloved Frederick James Willis, Esquire, to be Secretary to this Our Commission.

Given at Our Court at St. James's, the Seventh day of May, One thousand eight hundred and ninety-eight, in the Sixty-first Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. Ridley.

William Henry Power, Esq., f.r.s.,
To be a Member of the Royal Commission on Sewage Disposal.

VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Well-beloved William Henry Power, Esquire, Fellow of the Royal Society, Medical Officer of the Local Government Board: Greeting!

Whereas We did, by Warrant under Our Royal Sign Manual, bearing date the Seventh day of May, One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved cousin Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, or any three or more of them, to inquire into the treatment and disposal of sewage.

And whereas One of the Commissioners so appointed, namely, Sir Richard Thorne Thorne, has since deceased.

Now know Ye, that We, reposing great confidence in you, do, by these Presents, appoint you, the said William Henry Power, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Sir Richard Thorne Thorne, deceased, in addition to, and together with, the other Commissioners whom we have already appointed.

Given at our Court at Saint James's, the Seventh day of February, One thousand nine hundred, in the Sixty-third Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. Ridley.

Whitehall, March 18th, 1901.

THE KING has been pleased to issue a Commission, under His Majesty's Royal Sign Manual, to the following effect :—

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland King, Defender of the Faith, to all to whom these Presents shall come, Greeting !

Whereas it pleased Her late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified :

And whereas in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission ;
The Horse Breeding Commission ;
The Local Taxation Commission ;
The Port of London Commission ;
The Salmon Fisheries Commission ; and
The Sewage Disposal Commission ;

the Commissioners appointed by Her late Majesty, or such of them as were then acting as Commissioners, were, at the late demise of the Crown, still engaged upon the business entrusted to them :

And whereas We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown :

Now know Ye, that We, reposing great trust and confidence in the zeal, discretion, and ability of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissions do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration ; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the fourth day of March, One thousand nine hundred and one, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

THOMAS JOSEPH STAFFORD, F.R.C.S.I.,
To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith, To Our Trusty and Well-beloved Thomas Joseph Stafford, Esquire, Fellow of the Royal College of Surgeons of Ireland, Medical Commissioner of the Local Government Board for Ireland: Greeting!

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, to be Commissioners to inquire into the treatment and disposal of Sewage.

And whereas one of the Commissioners so appointed, namely, Our Trusty and Well-beloved Charles Philip Cotton, Esquire, hath humbly tendered unto Us his resignation of his appointment as one of the said Commissioners:

Now know Ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Thomas Joseph Stafford, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Charles Philip Cotton, resigned, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of May, One thousand nine hundred and two, in the Second Year of Our Reign.

By His Majesty's Command.
(Signed) CHAS. T. RITCHIE.

REGINALD ARTHUR TATTON, ESQUIRE,
To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R & I.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith, To Our Trusty and Well-beloved Reginald Arthur Tatton, Esquire, Greeting!

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May, One thousand eight hundred and ninety-eight, appoint Commissioners to inquire into the treatment and disposal of Sewage.

And whereas a vacancy has been caused in the body of the Commissioners appointed as aforesaid by the death of Major-General Constantine Phipps Carey, C.B.

Now know Ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Reginald Arthur Tatton, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Constantine Phipps Carey, deceased, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of January, One thousand nine hundred and seven, in the Sixth Year of Our Reign.

By His Majesty's Command.
(Signed) H. J. GLADSTONE.

REPORT.

To The King's Most Excellent Majesty:

We, the Commissioners appointed to inquire and report:—

I.—(1) What method or methods of treating and disposing of sewage (including any liquids from any factory or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of public health, and for the economical and efficient discharge of the duties of local authorities; and

(2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, the particular method of treatment and disposal to be adopted be determined; and

II.—To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage,

humbly report as follows:—

INTRODUCTION.

1. In this our fifth Report, we propose chiefly to deal with the relative merits of the various methods which are available for the purification of sewage of towns. In a subsequent report we shall deal with the various methods which are available for the purification of trade effluents, when not mixed with sewage.

2. The subject of sewage disposal has been inquired into by the following Committees and Commissions:—

1857. Commission to inquire into the best mode of distributing the sewage of towns and applying it to beneficial and profitable uses.

1862. Select Committee of the House of Commons to inquire into the best means of utilising the sewage of cities and towns of England, with a view to the reduction of local taxation and the benefit of agriculture.

1864. Select Committee of the House of Commons to inquire into any plans for dealing with the sewage of the Metropolis and other large towns, with a view to its utilisation for agricultural purposes.

1865. First Royal Commission to inquire into the best means of preventing the pollution of rivers.

1868. Second Royal Commission to inquire into the best means of preventing the pollution of rivers.

1869. Royal Commission to inquire into and report upon the operation and administration of the sanitary laws outside the Metropolis.

1875. Committee appointed by the President of the Local Government Board to inquire into the several modes of treating town sewage.

1882. Royal Commission to inquire into and report upon the system under which sewage is discharged into the Thames by the Metropolitan Board of Works, whether any evil effects result therefrom, and in that case what remedies can be applied for remedying or preventing the same.

3. The general conclusion of these bodies has been that sewage could only be properly purified by land treatment; and, as a consequence, it has been usual to require local authorities to adopt land treatment.

During recent years, however, certain methods differing from those which were considered by the earlier Commissions have been evolved, and, in view of the difficulty—or even impossibility—which many local authorities experience in obtaining adequate areas of suitable land at reasonable cost, it was considered desirable that these newer methods should be carefully investigated. This led to the appointment of our Commission.

4. One of the first steps taken by us after our appointment was to seek examples of these newer methods. We visited several places which were suggested to us, but in no case was the whole of the sewage of a town being dealt with; in most of the cases no more than a small and a constant quantity of sewage was being treated by the particular process. Moreover, the number of places in which experiments on anything approaching a practical scale were being carried on was very limited. We learnt, however, that for several towns it was proposed to adopt one or other of these newer processes, and we therefore decided to postpone experimental investigation into their merits until the field for observation was more extended.

1630. 5. One of our earliest witnesses, the late Mr. Santo Crimp, an engineer of wide experience, pointed out the danger of basing final conclusions as to a process on the results obtained with experimental plant, and there can be no doubt that inferences so founded must be drawn with caution, especially so when the amount of sewage being dealt with is a fixed quantity each day, and when the experiment does not adequately reproduce the many varying conditions which occur in practice.

Moreover, the weak points in a method of sewage disposal may sometimes only be disclosed after long experience covering a wide range of conditions.

Further, the character of the sewage of different towns varies to so great an extent that it would be unsafe to formulate definite conclusions as to the relative merits of different processes until experience had been gained of their sustained application to different types of sewage.

6. In our first Report we pointed out that at the time of the investigations of the earlier Commissions, the science of bacteriology was in its infancy; those Commissions, indeed, confined themselves almost entirely to a chemical examination of sewage effluents. Since the earlier Commissions reported, a large amount of exact knowledge has been gained concerning the part played by bacteria in various processes of nature and under conditions contrived by man, and it became our duty to study the various questions connected with sewage disposal, not only from a chemical, but also from a bacteriological point of view. This has largely increased our labours.

We have had to initiate and carry out various bacteriological investigations, and apprehending that the work done by earlier Commissions in regard to land treatment did not suffice for our purposes, we have found it necessary to include in our work a systematic and detailed investigation, bacteriological and chemical, of the treatment of sewage on land of various kinds.

PLAN OF WORK.

7. Our investigation has been carried on in the following manner :—

(I) We have held 144 meetings and called before us the following witnesses:—

Name.	Qualification.
Mr. Alfred D. Adrian, C.B.	Assistant Secretary to the Local Government Board (England and Wales).
Mr. A. Murray	Chief Clerk to the Local Government Board (Scotland).
Mr. L. E. H. Deane	Engineering Inspector to the Local Government Board (Ireland).
Mr. R. A. Tatton, M.Inst.C.E.	Chief Inspector to the Mersey and Irwell Joint Committee (1898).
Mr. F. Scudder, F.I.C., F.C.S.	Acting Chemist to the Mersey and Irwell Joint Committee under the supervision of Sir Henry Roscoe, F.R.S.
Mr. W. H. Wilson	Deputy Clerk and Solicitor to the Mersey and Irwell and Ribble Joint Committees.
Mr. W. Naylor, A.M.Inst.C.E., F.C.S.	Chief Inspector of the Ribble Joint Committee (1898).
Mr. Trevor Edwards	Clerk and Solicitor to the West Riding of Yorkshire Rivers Board.
Mr. H. Maclean Wilson, M.D., B.Sc.	Chief Inspector of the West Riding of Yorkshire Rivers Board.
Mr. Theodore Thomson, M.D.	Medical Inspector under the Local Government Board.
Mr. W. Santo Crimp, M.Inst.C.E., F.S.I.	Civil Engineer.
Mr. W. S. Curphey, F.I.C., F.C.S.	H.M. Inspector for Scotland under the Alkali Acts and the Rivers Pollution Prevention Acts.
Mr. Donald Cameron	City Surveyor of Exeter.
Mr. W. J. Dibdin, F.I.C., F.C.S.	Chemist.
Colonel Ducat	Inventor of the "Ducat" filter.
Mr. W. E. Adeney, D.Sc., F.I.C.	Curator and ex-Examiner in Chemistry in the Royal University, Dublin.
Mr. H. Marshall Ward, F.R.S., D.Sc.	Professor of Botany, University of Cambridge.
Dr. G. Sims Woodhead	Director of the Research Laboratories of the Conjoint Board of the Royal College of Physicians (Lond.) and the Royal College of Surgeons (Eng.).
Sir Edward Frankland, K.C.B.	Member of the Commission appointed in 1868 to inquire into the best means of preventing the pollution of rivers.
Mr. W. D. Scott Moncrieff, M.I.M.E.	Engineer.
Mr. J. Garfield, A.M.Inst.C.E.	Engineer in Charge of Sewage Disposal Works at Wolverhampton.
Sir Henry Roscoe, F.R.S., D.C.L., LL.D	Professor of Chemistry in the Owen's College, Victoria University, Manchester, and Scientific Adviser to the Mersey and Irwell Joint Committee.
Mr. Sidney Barwise, M.D. (Lond.), D.P.H. (Camb.)	County Medical Officer of Derbyshire.
Mr. S. Rideal, D.Sc., F.I.C.	Chemist.
Mr. Baldwin Latham, M.Inst.C.E., etc.	Civil Engineer.
Mr. C. J. Whittaker	Chairman of the Accrington and Church Outfall Sewage Works.
Mr. T. Cosham	Representing the Natural Purification Company.
Mr. A. P. Hope, F.C.S.	Representing the "Bacillite" Sewage Purification process.
Mr. H. B. Jagger	Representing the Carbonised Refuse System of Sewage Purification.
Mr. F. Wallis Stoddart, F.I.C., F.C.S.	City Analyst for Bristol.
Mr. W. Brown	Representing the Reeves Chemical Sanitation Company's process.
Mr. W. C. Sillar	Representing the "A.B.C." process.
Mr. Douglas Archibald	Representing the "A.B.C." process.
Mr. H. Wollheim	Representing the "Amines" process.
Mr. W. H. Harrison, M.Sc.	Chemist to the Leeds Sewage Committee.
Mr. W. Eason	City Surveyor of Ripon.
Mr. F. Bagshaw	Borough Surveyor of Harrogate.
Mr. Gilbert J. Fowler, D.Sc., F.I.C.	Superintendent and Chemist of the Manchester Corporation Sewage Works.

Name.	Qualification.
Mr. W. J. Newton, A.M.Inst.C.E.	Engineering Adviser to the Accrington and Church Outfall Sewage Board.
Mr. J. Barnes	Superintendent Chemist in Charge of the Accrington and Church Outfall Sewage Works.
Dr. A. C. Houston	Bacteriologist to Commission.
Dr. G. McGowan	Chemist to Commission.
Mr. G. Chatterton, M.Inst.C.E.	Civil Engineer.
Mr. D. Balfour, M.Inst.C.E.	Civil Engineer.
Mr. W. H. Prescott	Borough Engineer of Reigate.
Mr. Frank Candy	Surveyor and Sanitary Engineer of the International Purification Syndicate.
Colonel Harding	Member of the Commission and Chairman of the Leeds Sewerage Committee.
Mr. G. R. Strachan, M.Inst.C.E.	Civil Engineer.
Mr. Alderman H. F. Hibbert	Chairman of the Chorley Sewage Works and member of the Ribble Joint Committee.
Mr. E. G. Mawbey, M.Inst.C.E.	Borough Engineer of Leicester.
Prof. E. A. Letts, D.Sc., F.I.C., Ph.D.	Professor of Chemistry at Queen's College, Belfast.
Prof. W. A. Herdman, D.Sc., F.R.S.	University College, Liverpool, and Honorary Director of Scientific Work to the Lancashire and Western Sea Fisheries Committee.
The Hon. T. H. W. Pelham	Assistant Secretary to the Board of Trade.
Mr. J. C. Thresh, M.D., D.Sc., D.Ph., F.I.C.	Medical Officer of Health of the Essex County Council.
Mr. T. E. Hill, M.D.	County Medical Officer, Durham.
Mr. G. V. Poore, M.D., F.R.C.P.	Professor of Medicine at University College, London.
Mr. E. E. Klein, M.D., F.R.S.	Chemist and Bacteriologist.
Mr. W. Williams, M.A., M.D., D.Ph. (Oxon), M.R.C.S., F.C.S., etc.	Medical Officer of Health to the Glamorgan County Council.
Dr. P. F. Frankland, F.R.S.	Professor of Chemistry in the University of Birmingham.
Dr. J. A. Voelcker	Consulting Chemist to the Royal Agricultural Society.
Mr. A. F. Firth	Managing Director of Messrs. T. F. Firth and Sons.
Mr. H. Beaumont	Fulling Miller and Finisher.
Mr. J. Crowther	Chairman of the West Riding of Yorkshire Millowners' and Occupiers' Association.
Mr. G. C. Hirst	Woollen Manufacturer.
Mr. J. Bruce	Manager of Tanneries and Currying Works.
Mr. E. Butterworth	Flannel Manufacturer.
Mr. H. A. Foster	Managing Director of Alpaca and Mohair Spinning Works and Manufactories.
Mr. G. Sheard	Woollen Manufacturer.
Mr. W. E. Walker	Tanner.
Mr. Harvey	Tanner.
Mr. J. Stanning Mr. Ross Gemmell Mr. A. J. King	Representing the Calico Printers' Association, Ltd., and Bleachers' Association, Ltd.
Mr. J. H. Mills	Clerk and Surveyor to the Crompton Urban District Council.
Mr. Alderman J. T. Simpson	Chairman of the Halifax Sewage Committee.
Mr. J. Lord	Engineer to the Halifax Sewage Committee.
Mr. Keighley Walton	Town Clerk of Halifax.
Mr. J. Jones	Borough Surveyor of Pudsey.
Mr. W. Hopkinson	Borough Surveyor of Keighley.
Mr. J. E. Sharpe	Engineer and Surveyor of Otley.
Mr. B. Powell	Engineer and Surveyor of Handsworth.
Mr. A. E. Fletcher, F.I.C.	Inspector under the Alkali Acts.
Mr. T. Carter Beeley, J.P.	Mayor of Hyde.
Mr. S. S. Platt, M.Inst.C.E.	Borough Engineer of Rochdale.
Mr. T. Stenhouse, F.I.C., F.C.S.	Public Analyst of Rochdale.
Mr. E. Ll. Morgan, A.M.Inst.C.E.	Borough Engineer of Bolton.
Mr. J. Ashton, F.C.S., F.I.S.E.	Chemist and Manager of the Bolton Sewage Works.

Name.	Qualification.
Mr. R. Johnson	Chairman of the Sewage Committee of Bradford.
Mr. E. A. Brotherton, M.P.	Manager Director of Manufacturing Works.
Mr. D. Howard, F.I.C., F.C.S.	Chemical Manufacturer.
Mr. C. A. Davis	Owner of Dyeworks.
Mr. W. F. Reid, C.E., F.C.S., F.I.C.	Vice-President of the Society of Chemical Industry.
Mr. H. Marshall Mr. C. W. Crossley Mr. P. G. Baldwin Mr. J. Smith	Representing the Halifax Traders' Committee.
Sir Charles A. Cameron, M.D.	Public Officer of Health in the City of Dublin.
Mr. S. Harty, C.E.	Engineer to the Dublin Corporation.
Mr. M. F. Purcell, M.Inst.C.E.	Civil Engineer.
Mr. Forbes Watson	Chemist to Messrs. Guinness, brewers.
Mr. J. C. Bretland, M.Inst.C.E.	City Surveyor of Belfast.
Dr. Lorrain Smith	Professor of Pathology at Queen's College, Belfast.
Mr. George Giles, M.Inst.C.E.	Chief Engineer to Belfast Harbour Commissioners.
Dr. W. S. Squire	Representing the Society of Chemical Industry.
Mr. Alderman Ellis	Tanner.
Mr. Thorp Whitaker	Representing the Bradford Dyers' Association.
Alderman Sir Bosdin T. Leech	Chairman of the Manchester Rivers Committee.
Councillor C. Dreyfus	Deputy Chairman of the Manchester Rivers Committee.
Mr. J. D. Watson, M.Inst. C.E.	Engineer and General Manager to the Birmingham, Tame, and Rea District Drainage Board.
Mr. C. F. Wike, M.Inst.C.E.	City Surveyor and Engineer of the Sheffield Sewage Works.
Mr. J. Haworth, F.C.S.	Chemist of the Sheffield Sewage Works.
Mr. T. Hewson, M.Inst.C.E.	City Engineer of Leeds.
Mr. J. Garfield, A.M.Inst.C.E.	Engineer of the Bradford Sewage Works.
Mr. G. H. Pickles, A.M.Inst.C.E.	Borough Surveyor, Burnley.
Mr. Raymond Ross, F.I.C., F.C.S.	Borough Analyst, Burnley.
Mr. J. Corbett	Engineer of the Salford Sewage Works.
Mr. J. Carter Bell, F.C.S.	Public Analyst.
Mr. J. Arnold	Manager of the Salford Sewage Works.
Mr. James B. Wilkinson, M.D. (Edin.), D.P.H., F.C.S.	Medical Officer of Health, Oldham.
Mr. A. H. Valentine, M.Sc.	Analytical Chemist, Oldham.
Mr. H. T. Bulstrode, M.A., M.D.	Medical Inspector of the Local Government Board
Mr. Phillips	Master of the Brewers' Company.
Mr. H. H. Waller	Vice-President of the West Riding Urban and Rural District Councils' Association.
Mr. R. B. Emsley	Solicitor to the West Riding Urban and Rural District Councils' Association.
Mr. W. B. Pindar	Secretary to the West Riding Urban and Rural District Councils' Association.
Mr. J. S. Martin	H.M. Inspector of Mines.
Captain Anderson	Chairman of the Whitstable Oyster Fishery Company.
Mr. Charles Petrie	Alderman of the City of Liverpool.
Mr. J. Wrench Towse	Clerk of the Fishmongers' Company.
Mr. R. A. Dawson	Representing the Lancashire and Western Sea Fisheries Committee.
Mr. H. Donnison	Representing the Eastern Sea Fisheries Committee.
Mr. H. W. Gibson	Representing the Kent and Essex Sea Fisheries Committee.
Mr. J. Cole	Oyster Merchant, Poole.
Mr. A. L. Scott	Oyster Merchant, Poole.
Mr. A. Brazier	Oyster Merchant, Southwick.
Mr. J. Kennett	Oyster Merchant, Emsworth.
Sir William Pink Mr. St. Barbe	Representing the Southern Sea Fisheries Committee.
Mr. G. H. Baxter	Representing the Chamber of Fisheries.
Mr. J. T. C. Nash, M.D. (Edin), D.P.H.	Medical Officer of Health, Southend-on-Sea.

Name.	Qualification.
Mr. W. J. Bean	Oyster Merchant, West Mersea.
Mr. James Blamey, M.R.C.S.	Medical Officer of Health, Penryn.
Mr. Arthur Newsholme M.D., F.R.C.P. (Lond.)	Medical Officer of Health, Brighton.
Mr. James Niven, M.B.	Medical Officer of Health, Manchester.
Mr. J. H. Barber	Secretary of the Chamber of Fisheries and the London Fish Trade Association.
Mr. William G. Savage, M.D., B.Sc., D.P.H.	Medical Officer of Health, Colchester.
Mr. M. Fitzmaurice, C.M.G.	Chief Engineer of the London County Council.
Prof. Frank Clowes, D.Sc., F.I.C.	Chemist of the London County Council.
Mr. H. Williams, M.D.	Medical Officer of Health, Port of London.
Sir Shirley Forster Murphy, M.R.C.S.	Medical Officer of Health, London County Council.
Mr. C. C. Hutchinson	Counsel to the Lee Conservancy.
Mr. Geo. Corble	Clerk to the Lee Conservancy.
Messrs. Clapham and Fitch	Solicitors to the Lee Conservancy.
Mr. C. N. Tween	Engineer to the Lee Conservancy.
Mr. W. C. Young	Chemist to the Lee Conservancy.
Mr. R. B. Croft	Chairman of the Lee Conservancy.
Mr. E. B. Barnard	Member of the Lee Conservancy.
Mr. H. Nield	Member of the Lee Conservancy.
Mr. R. Phillipson	Secretary to the Thames Conservancy.
Mr. F. A. W. Drummond	Chief Inspector to the Thames Conservancy.
Mr. C. E. Groves	Analytical Chemist to the Thames Conservancy.
Dr. T. J. Browne	Medical Inspector, Local Government Board, Ireland.
Prof. E. J. McWeeney, M.A., M.D., D.Ph.	Bacteriologist to the Local Government Board for Ireland.
Mr. E. W. L. Holt	Scientific Adviser to Department of Agriculture, Ireland.
Dr. Cowie	Representing the South, East, West, and North of Scotland Malt Distillers' Association.
Mr. Allan	
Mr. Thorne	
Mr. Hopkins	
Mr. J. Robertson	
Mr. Doig	
Mr. Grant Glen Grant	
Mr. Fergusson	
Mr. Brown	
Mr. Mustard	
The Duke of Richmond and Gordon	Representing Riparian Owners in Scotland.
Mr. J. R. Findlay	
Mr. W. S. Menzies	
Mr. J. H. W. Grant	
Mr. Herbert Hughes, C.M.G.	Clerk of the Millowners' Association.
Mr. J. Selwyn Rawson	Millowner.
Mr. A. F. Somerville	Chairman of the Sanitary Committee of the Somerset County Council.
Mr. E. Halliwell	Chief Inspector of the Ribble Joint Committee.
Mr. George Reid, M.D., D.P.H.	Medical Officer of Health of the Staffordshire County Council.
Mr. J. Bolton	Manager of the Heywood Borough Sewage Purification Works.
Mr. J. H. Kershaw, F.C.S.	Chemist and Manager of the Corporation Sewage Works, Rotherham.
Mr. K. F. Campbell, M.Inst.C.E.	Borough Engineer of Huddersfield.
Mr. O. J. Kirby	Borough Engineer of Batley.
Mr. J. P. Wilkinson, M.Inst.C.E.	Engineer of the Manchester Sewage Works.
Mr. F. R. O'Shaughnessy, A.R.C.Sc., F.I.C.	Chemist to the Birmingham, Tame, and Rea District Drainage Board.
Mr. Geo. Watson, M.Inst.M.E., A. M.Inst.C.E.	Managing Director of the Horsfall Destructor Co.
Mr. W. F. Goodrich, A.M.Inst.M.E.	London Manager, Messrs. Meldrum Bros., Ltd.
Mr. J. E. Willcox, M.Inst.C.E.	Civil Engineer.

Name.	Qualification.
Mr. H. P. Raikes, A.M.Inst.C.E.	Civil Engineer.
Mr. J. Hunter, F.I.C., F.C.S.	Consulting Chemist.
Mr. J. B. Readman, D.Sc., F.R.S. (Edin.)	Consulting Chemist.
Mr. R. R. Tatlock, F.R.S. (Edin.), F.I.C., F.C.S.	Consulting Chemist.
Mr. J. H. Fullarton, M.A., D.Sc.	Formerly Scientific Adviser to the Fishery Board for Scotland.
Mr. Jas. Hendrick, B.Sc., F.I.C.	Public Analyst for the Counties of Aberdeen, Banff and Nairn.
Mr. Stevenson Macadam, F.I.C., F.C.S.	Analytical and Consulting Chemist.

(II) We have, by means of circular letters, obtained a large amount of assistance from many scientific men who have had special experience in regard to the subject of sewage disposal.

(III) A number of local authorities have carried out experimental investigations in association with the Commission, and have been good enough to furnish us with monthly records of the results of their experiments. These towns are as follows :—

Birmingham.	Leeds.	Rotherham.
Burnley.	Manchester.	Salford.
Heywood.	Oldham.	Sheffield.
Huddersfield.		

The reports furnished by these authorities are printed with the evidence. In each case the officers responsible for the local investigations were called before us to give evidence.

(IV) We have put under the systematic observation of our own officers a number of sewage farms and sewage works of different types.

The officers' reports on their observations of artificial processes are issued with this report as Appendix III. Their reports on the sewage farms were issued as an Appendix to our Fourth Report.

(V) We have carried out the following special investigations :—

Place at which the experiment was carried out.	Object of experiment.
Accrington	(*a*) For the purpose of ascertaining the relative difficulty of treating the same tank liquor, diluted and undiluted, on contact beds and on percolating filters. (*b*) To compare the purification effected in each instance by these two types of filter, under similar conditions in the one and in the other case.
Dorking	(*a*) For the purpose mainly of comparing septic tank liquor, precipitation liquor, and settled sewage derived from the same sewage, as to their amenability to subsequent oxidation by filtration. (*b*) To compare the reduction of suspended matter in the same sewage effected by the different processes of tank treatment, and to ascertain the quantities of sludge produced in each case. (*c*) Removal of suspended matter from percolating filter effluents. (*d*) Reduction in number of intestinal organisms in filtrates by means of sterilising agents, and comparison of the results obtained by this method with the effect of filtration through sand. (*e*) Comparative values of deep and shallow filters. [*See also* Ilford.]
Exeter (Belle Isle)	Digestion of sludge in septic tank. [*See also* Ilford.]
Guildford	For the purpose of ascertaining whether, by the addition of "oxychloride" solution to septic tank liquors, the unpleasant smell actually developed by such liquor may be destroyed without impairing the ability of the filter, subsequently dealing with the liquor so treated, to effect the requisite purification.
Hendon	Sterilisation of effluents.
Ilford	(*a*) Digestion of sludge in septic tank. (*b*) Comparative values of deep and shallow filters.

At some of these places channels have been provided along which the effluent has been allowed to flow, the main object being to ascertain whether effluents liable to bring about undesirable changes in the condition of a stream into which they are discharged can be clearly distinguished by chemical test from those which do not.

(VI) We have personally visited a large number of sewage works.

8. We wish to express our great indebtedness to the several local authorities, and to the many gentlemen from whom we have received assistance. Their names are far too numerous to mention.

Appendices to Report.

9. The following volumes are presented as appendices to this report :—

(I) The Evidence of Witnesses.

(II) A Summary of the Evidence.

In preparing this report we found it necessary to make a summary of the evidence.

The plan which was followed was to divide the subject up into chapters such as sewage, storm-waters, sedimentation tanks, septic tanks, standards, and so on, and then to sub-divide each chapter.

The evidence given on questions of primary importance was thus very briefly summarised and brought together.

We think that this summary may possibly be of general utility and we have therefore decided to publish it, but of course the evidence itself should be consulted by anyone wishing to make a complete study of the subject.

(III) Reports on the observations of artificial processes at the following places :—

Accrington.	Halton.	Maidstone.
Andover.	Hampton.	Newton le Willows.
Calverley.	Hartley Wintney.	Normanton.
Caterham.	Hendon.	Oswestry.
Chorley.	Hendon (Ducat filter).	Prestolee.
Clifton.	Horfield.	Rochdale.
Exeter (Main Works).	Kingston-upon-Thames.	Slaithwaite.
Exeter (St. Leonard's).	Knowle.	Withnell.
Guildford.	Little Drayton.	York.

(IV) Reports on the special investigations, mentioned on page 7, at Accrington, Dorking, Exeter, Guildford, Hendon, and Ilford.

Memorandum by Mr. Frye upon experiments carried out at Oldbury on the treatment of the sewage of that town.

Memorandum by Dr. McGowan as to measuring strength of sewage.

Report by Dr. McGowan and Mr. Frye on the estimation of the work done by filters which have been under the observation of the Commission.

Report by Dr. Houston on laboratory experiments on the biological purification of sewage.

Report by Dr. Houston on the biological character of B. coli in sewage and sewage effluents.

Reports by Dr. Houston on the results of the bacteriological examination of sewage and effluents from the sewage works at Bradford, Leeds, Manchester, and Ilford.

Report by Dr. Houston and Dr. McGowan on the sterilisation of the Lincoln water.

(V) Reports by Mr. Baldwin Latham, M.Inst.C.E., and Mr. R. A. Tatton, M.Inst.C.E., upon the effect of rainfall on the flow of sewage.

(VI) A report by Professor Letts and Dr. Adeney on the pollution of estuaries and tidal waters. In regard to this we may refer to paragraph 116 of our fourth Report, which was as follows :—

> "In connection with the question of standards as regards offensive putrefaction and injury to fish, we may state that much work has already been done, both in this country and abroad. We have therefore thought it desirable that the results of this work should be collected and collated. Mr. E. A. Letts, D.Sc., F.I.C., Ph.D., Professor of Chemistry at Queen's College, Belfast, and Mr. W. E. Adeney, D.Sc., Vice-President of the Institute of Chemistry, Curator and Examiner in Chemistry in the Royal University, Dublin, have kindly arranged to do this and to report to us on the question how far these results may suffice to show the conditions under which tidal rivers would become, (*a*) a nuisance in consequence of offensive putrefaction or (*b*) injurious to fish, either in consequence of the diminution of oxygen or the presence of poisons. The results so collected will, we hope, be of considerable use in enabling each Rivers Board to deal with waters under its jurisdiction."

To this report is appended a Paper by Mr. Gilbert J. Fowler, D.Sc., F.I.C., on the effects of discharge of septic tank sludge into a tidal estuary.

(VII) A copy of a circular letter on the question of standards for sewage effluents, and of the replies which were sent to us by chemists and others.

(VIII) Reports by Mr. W. Somerville, D.Sc., Mr. T. H. Middleton, M.A., M.Sc., and Dr. J. A. Voelcker upon experiments on the manurial value of sewage sludge.

Terms of Reference.

10. The first paragraph of the Terms of Reference requires us to state how (*a*) sewage, (*b*) sewage and trade effluents, and (*c*) trade effluents alone, may be properly treated or disposed of having regard to the requirements of

I.—The existing law.
II.—Public health.
III.—Economy and efficiency.

The second paragraph requires us to report by what rules, in relation to varying circumstances or requirements, should the particular method to be adopted be determined.

These terms open up a wide field of inquiry, and the second paragraph involves intimate study of various methods of treatment, many of which are new, under a very large number of different conditions.

GENERAL CONCLUSION.

11. Before dealing in detail with the numerous questions involved in our inquiry, we think it will be convenient that we should at once state our general conclusion on the question contained in the first paragraph of our Terms of Reference.

We are satisfied that it is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters, and that there is no essential difference between the two processes, for in each case the purification, so far as it is not mechanical, is chiefly effected by means of micro-organisms. The two main questions, therefore, to be considered in the case of a town proposing to adopt a system of sewage purification are, first, what degree of purification is required in the circumstances of that town and of the river or stream into which its liquid refuse is to be discharged; and, second, how the degree of purification required can, in the particular case, be most economically obtained.

The choice of a scheme must depend on a number of considerations which will be discussed later, but we may here state that we know of no case where the admixture of trade refuse with the sewage makes it impracticable to purify the sewage either upon land or by means of artificial processes, although in certain extreme cases special processes of preliminary treatment may be necessary.

PLAN OF REPORT

12. We propose to divide this Report into the following parts :—

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PART I. PRELIMINARY TREATMENT OF SEWAGE.

INTRODUCTORY REMARKS.

13. Sewage generally may be said to consist of a mixture of saline matter in solution and nitrogenous and carbonaceous organic matter in solution and suspension together with a certain amount of grit and mineral matter. The objects to be aimed at in its purification are the removal of the suspended matters and the oxidation of the remaining organic matter and ammonia.

There is a considerable amount of evidence to show that the oxidation of the organic matter during its passage through filters or land is chiefly a biological process, but as to the exact nature of the action which takes place very little is known.

One of our chemists, Mr. Colin Frye, carried out a * series of experiments at Leeds, in which he showed that, although a mature filter could not appreciably oxidise sewage sterilised with corrosive sublimate, it could oxidise sewage which had been sterilised with steam. Further, that a sterile filter could not appreciably oxidise sterile sewage.

We may also refer to some experiments which Dr. Houston, our bacteriologist, made during the year 1903. (Report by Dr. Houston on laboratory experiments on the biological purification of sewage: contained in Appendix IV.)

These experiments seem to suggest that the presence of such non-sporing bacteria as B. coli, B. proteus, etc., are not *essential* to purification, and that the work may be performed by other micro-organisms.

They also show that, although a filter may contain initially an enormous number of B. coli, if the liquid passing on to the filter contains none of these micro-organisms, this microbe rapidly disappears from the effluent, although the filter may still be able to support the life of many other bacteria. It is therefore to be inferred that sewage filters, when working properly, are not likely to provide suitable breeding grounds for pathogenic bacteria, although they allow a certain number of such bacteria to pass through them.

14. As regards the fermentative changes which occur in the purification of sewage, Dr. Adeney has made a large number of valuable experiments. His results have been published from time to time in the Transactions of the Royal Dublin Society, and in the proceedings of the Royal Irish Academy, and a connected account of the work is included in the † Report, which he and Dr. Letts have presented to the Commission on the Pollution of Estuaries and Tidal waters.

Dr. Adeney founds the following general conclusions on his work :—

General Summary.

" In the foregoing pages the chemical changes, which occur in a polluted water during so-called self-purification under aerobic conditions, and the laws underlying them, have been traced and established ; and this has necessitated the discussion in minute detail of a large amount of experimental evidence of a varied character. A brief summary of the results arrived at, apart from experimental details, may therefore prove of some convenience to those interested in the subject.

" The most important change which occurs in an unpolluted water, when it is mixed with sewage or other water-borne refuse matters, is the more or less rapid absorption of its dissolved oxygen.

" The absorption may be effected in three different ways :—(1) The polluted water, from its own state of total or comparative de-aeration, reduces the aeration of the unpolluted water by simple dilution ; (2) the polluted water may contain directly and easily oxidisable substances, which on becoming mixed with the unpolluted water will cause a more or less rapid loss of its dissolved oxygen ; (3) the organic constituents of the sewage, which are not directly oxidisable (and they usually form the greater portion of the organic substances in it), and the ammonium compounds, are oxidised through the agency of water bacteria, and thus indirectly cause a loss of dissolved oxygen.

" These possible causes of de-aeration are enumerated in the order in which they would in all probability take effect under natural conditions. The first is obvious, although its importance has not been sufficiently recognised. Its effect can easily be differentiated from the other two, if the amount of dissolved oxygen, or as it is generally termed, the degree of aeration of the polluted water, be first determined, and this can be done without difficulty either by a gasometric or volumetric method.

* For a description of these experiments *see* our Second Report, Cd. 1178 [1902].
† *See* Appendix VI.

"The second cause of de-aeration is equally obvious, although its importance has also not been sufficiently realized. Such experiments as those recorded in Tables 34, 35, 35A, 36, and 37 prove that directly oxidisable bodies, from the rapidity with which they absorb oxygen, constitute a greater danger to the aeration of the water with which they become mixed than do indirectly oxidisable substances. Hence it is necessary to know the rate of absorption of oxygen caused by them as well as by indirectly oxidisable substances.

"It is impossible to foretell the influence of these two causes of de-aeration from any information derivable from the ordinary methods of chemical analysis. It is, however, possible to do so by means of the aeration method, and the foregoing pages have been largely devoted to a description of that method, and of the experimental investigation upon which it is based.

"A study of indirect oxidation by this method has shown that it is a physiological process analogous to the respiratory process of higher vegetable systems; but that it is only one, although the principal one, of a number of physiological processes concerned in the self-purification of a polluted water under aerobic conditions.

"It is unnecessary to discuss these in detail. It is sufficient for the study of polluted waters to recognise the possibility of processes of digestion (by enzymes), and to regard the remainder as together exercising one function, viz., the synthesis of the constructive materials required for the growth and multiplication of the bacteria, and at the same time to remember that there must result from these synthetical processes waste or by-products, which may be regarded as excretory substances.

"The chemical changes which are produced by the above processes may collectively be termed fermentative changes for convenience of reference.

"Experiments with samples of sewage and of polluted waters, of various descriptions, have been made, and it has been found that when they were severally mixed with unpolluted water in small proportions, within the limits of fouling, the fermentative changes which follow exhibit a definite and regular sequence. The organic matters first suffer complete fermentation, the products of change being carbonic acid, water, ammonia, and organic substances possessing the chemical and physical properties of the humus of cultivated soils, and of the organic substances to be found in all unpolluted natural waters, especially in those from upland surfaces.

"A second stage of change subsequently ensues, in which these humus matters and the ammonium compounds are further fermented, the resulting products being carbonic acid, nitric acid and water.

"The inorganic products of the first stage of fermentation result from the action of the respiratory process, and possibly also of enzymes; and the humus-like substances are waste products from the synthetical processes.

"It is a point of interest to note that free nitrogen has not been observed amongst the products of the fermentation of organic substances in water under aerobic conditions, although it does undoubtedly occur amongst the products of fermentation in percolating filters even when the conditions therein are wholly aerobic. It is a question, no doubt, of intensity of oxidation. The filter presents conditions for an extremely rapid and intense oxidation; while water in large bulk, owing to the sparing solubility of oxygen in it, can only allow a sluggish oxidation to proceed in it.

"Experiments with distilled water solutions of simple organic substances of known composition have shown that the respiratory process is one of simple oxidation, and that the organic matters affected by it are completely oxidised to the inorganic products, carbonic acid, ammonia and water. The oxidation may either be complete step by step as the fermentation proceeds, or only partial at first but finally complete, according to the chemical properties of the substances undergoing fermentation.

"In the simple solutions employed in these experiments, it was evident from the composition of the organic substance dissolved in each and from the ratio of the carbon dioxide formed to oxygen absorbed, on its complete fermentation, that the oxygen was almost, if not entirely, taken up by the respiratory process. Other experiments, however, have shown that it is quite possible under certain exceptional conditions as to the composition of the fermenting substances, for the synthetic processes to take up relatively considerable quantities of oxygen. Whether oxygen is or is not taken up by these processes appears to be a question of composition of the fermenting substance, as might be expected. In ordinary cases, however, of polluted waters, the composition of the polluting substances generally appears to be such that during their fermentation the absorption of oxygen is practically confined to the respiratory process.

"Enzymic action is intimately associated with the respiratory process in the fermentation of many organic substances. The chemical changes induced by them are principally hydrolytic, and the products are generally simplifications of the original body; and these undergo further fermentative change. Only in the case of urea do they bring about a complete change to the ultimate products, carbon dioxide and ammonia.

"Sometimes enzymic changes occur with almost explosive velocity; *e.g.*, asparagin, when present in the fermenting water, is hydrolysed with extreme rapidity, the whole of it being converted into aspartic acid and ammonia at the very commencement of the fermentation, the hydrolysed product, aspartic acid, then undergoing complete fermentation.

"In other cases, enzymic change may proceed extremely slowly, very much more so than the other fermentative changes which may be going on in the same water. Urea when present in some polluted waters is an example of this.

"There are some other substances which may occur in polluted waters, *e.g.*, native albumins and fats, which require to undergo enzymic change before they can be readily fermented by water bacteria.

" The chemical changes which are brought about by the respiratory process and by enzymes may be regarded as yielding a continual supply of energy to the bacteria. They effect the complete oxidation of 70 to 80 per cent. of the organic substances originally present in the polluted water.

" The new material resulting from the synthetical process accounts probably for about 5 per cent., or even less, and the waste products for the remaining 15 to 25 per cent.

" As regards possible relationships between the volume of carbon dioxide formed to oxygen absorbed in a polluted water, it is obvious there can be no very definite one, especially when the water contains directly and easily oxidisable substances, *e.g.*, sulphides, etc., in addition to indirectly oxidisable ones. As a matter of fact, however, in the case of most waters polluted by fresh sewage, a fairly constant relationship has been observed, the ratio of carbon dioxide to oxygen being approximately as 1 : 1. If the sewage be putrefactive and contain sulphides, the ratio may be much less, *e.g.*, the ratio for the septic tank liquor employed for the experiments recorded in Table 39 is as 1 : 1·3.

" After the completion of the fermentation of the organic matters, a second stage of change, as already noted, sets in, and during it the products of the first stage, that is, the ammonium compounds and the humus matters, undergo further fermentation. As a result the former are completely oxidised to nitric acid and the latter more or less completely to carbon dioxide and nitric acid. The point of interest and importance in this stage of fermentative changes is the influence of the humus matters on the oxidation of the ammonium compounds.

" Laboratory experiments have shown that they not only accelerate the fermentative changes, but that their presence is necessary for the oxidation of the ammonium compounds to nitric acid. When they are entirely absent, the oxidation is not carried under ordinary conditions beyond nitrous acid.

" When the ammonium compounds are present in slight excess of the humus matters, both may be completely fermented, the inorganic products being carbon dioxide, water and nitric acid.

" The changes which humus matters may undergo when in excess of the ammonium compound appears to be very variable. For example, when fresh, a portion of their carbon is readily oxidised to carbon dioxide, and then, if unassociated with compounds of ammonia, they cease to undergo much further change.

" The volume of oxygen actually absorbed in the second stage of fermentation does not bear a constant ratio to the oxygen theoretically equivalent to the nitrous and nitric oxides formed. The volume may be greater than the theoretical, in the proportion of 10 : 8·14 (Table 19, Experiment 1 and 1*a*), if humus matters are wholly absent ; or less, *e.g.*, 10 : 13·5 (Table 19, Experiment 2), if these are present in large quantities and are freshly formed.

" Where, as in ordinary cases of polluted tidal waters, humus matters are unlikely to be present in any but small proportions, the volume of oxygen required for the oxidation of the ammonia to nitric acid can be calculated with sufficient accuracy from the equation :—

$$2\ NH_3 + 4\ O_2 = N_2O_5 + 3\ H_2O.$$

" On comparing together the changes which progressively occur in the two stages of fermentation which have been described, it becomes evident that the oxidation of ammoniacal nitrogen to nitrous and nitric acids constitutes the central feature of the second stage, just as the oxidation of organic carbon to carbon dioxide constitutes the central feature of the first stage. It may be concluded, therefore, that the products nitrous and nitric acids of the one stage are the analogues of the product carbon dioxide of the other stage. The first stage of fermentation may consequently be termed the carbon-oxidation stage, and the second the nitrogen-oxidation stage. These terms have the advantage of emphasising a fact which it is necessary to keep in mind in dealing with the subject of water pollution ; it is that the sequence of the chemical changes, which occur during self-purification under aerobic conditions, takes place in accordance with thermo-chemical principles.

" A classification of the substances which may occur in polluted waters may be made, based on their behaviour towards the dissolved oxygen of the water, as follows :—

(1) Directly oxidisable substances.
(2) Indirectly oxidisable substances.

" These latter may be further sub-divided, according to their fermentative properties into—

(*a*) Carbon oxidisable substances, that is, most known organic substances except antiseptics.
(*b*) Nitrogen fermentable substances, that is, the waste products from a first stage fermentation, and ammonium compounds.

" Not only do the fermentative changes in a polluted water follow a definite and regular sequence, but the relationship between the oxygen absorbed and the products formed, and between both of these and the quantities of polluting matters originally present, are quantitative according to the following law :—The quantities of oxygen absorbed, and of products formed, on the completion of each stage of aerobic fermentation, is constant for similar volumes of the same polluted water, provided that the dissolved oxygen is in excess of the fermenting matters.

" It must be granted from the above brief description of the fermentative changes which occur in a water during self-purification under aerobic conditions, that the significance of the presence of indirectly oxidisable substances in water depends not upon their exact quantity and chemical composition, but upon their fermentative properties and on the rate at which they will absorb oxygen from the waters with which they are mixed The same remark applies with equal force to directly oxidisable substances."

" It must also be granted that the methods which are at present employed for the analysis of sewage and of sewage effluents, which were originally worked out for the analysis of potable waters, do not afford information of this kind. The aeration method has consequently been proposed for the purpose. As may be gathered from the perusal of pp. 67–91 it is possible to determine by its means the rate of absorption as well as the total absorption, of oxygen which a sewage or sewage effluent is capable of setting up when mixed

in small proportions with unpolluted river or tidal water, during direct oxidation as well as during both stages of indirect oxidation. From the description of the method given on p. 96, it will be seen that several modifications in working can be adopted according to the object in view, that is to say, whether it be desired to study the fermentative changes step by step in their entirety, or simply to determine the rate of, or total, absorption of oxygen during them. The modifications required for the latter purpose can be so simply operated that untrained persons can be taught to carry them out without difficulty.

"Another phase of the subject of the self-purification of slightly polluted waters, and a scarcely less important one, is the rate at which the dissolved oxygen in such is replenished from the atmosphere under natural conditions, when it is being absorbed by polluting matters. It is obvious that definite information is required on this question before it will be possible to formulate standards of impurity for the protection of river and tidal waters from over-pollution.

"Experiments have been described which afford some fairly trustworthy information on this subject. The results of these experiments were quite unexpected, since they show that the slow rate of re-aeration of large volumes of de-aerated tidal water under calm weather conditions is not due to the slow process of mixing by thermal current or of diffusion of the dissolved gas after it has been taken up in solution by the surface layers of the waters exposed to the air. On the contrary, it has been shown that the slowness of re-aeration is due to retardation of the process of solution at the water's surface, and that when oxygen has become dissolved at the surface from the atmosphere, it is drawn with comparative speed through the water, apparently by some unexplained process of gravitational streaming. It has also been shown that long columns (6 feet) of de-aerated fresh or sea water enclosed in narrow glass tubes of small bore are comparatively quickly re-aerated when the surfaces of the columns were kept continuously broken, either by a mechanical stirrer or by a slow current of air delivered by an inlet tube dipping a little below the surface.

"It has, furthermore, been found from these experiments that the aeration of the sea water columns was effected much more rapidly than that of the fresh water columns, and that the dissolved gases showed practically no tendency to accumulate in the surface layers of the sea water columns, but passed almost as quickly through them as they were dissolved, with the result that the degree of aeration of the water is found to be nearly uniform throughout the length of the column, if it be tested at different depths at any time during the process of aeration; while in the case of the fresh water columns the dissolved gases did show a tendency to accumulate in the upper layers, and did not pass so rapidly to the lower layers."

15. Dr. Fowler, Professor Frankland, Mr. Harrison, Dr. Letts, Dr. Reid, Mr. Stoddart, Dr. W. Owen Travis and many others have also carried out numerous experiments with a view of elucidating some of the scientific questions involved in the purification of sewage, but notwithstanding the fact that a considerable amount of exact knowledge has been gained as the result of the experimental investigations which have been already made, there are many questions in regard to which our knowledge is exceedingly limited.

As regards the actual disposal of sewage on a practical scale, Colonel Harding and Mr. W. H. Harrison, at Leeds; Dr. Fowler, at Manchester; Mr. J. D. Watson and Mr. F. R. O'Shaughnessy, at Birmingham; Messrs. Willcox and Raikes, and Dr. George Reid at Hanley, Newcastle-under-Lyme, and elsewhere; Mr. A. H. Valentine and Dr. J. B. Wilkinson, at Oldham; Messrs. Raymond Ross and G. H. Pickles, at Burnley; Mr. Joshua Bolton, at Heywood; Mr. J. H. Kershaw, at Rotherham; Mr. K. F. Campbell, at Huddersfield; Mr. J. Carter Bell, at Salford; Mr. C. F. Wike and Mr. J. Haworth, at Sheffield, and others have carried out many valuable experiments in regard to certain methods of purifying sewage. These gentlemen have placed before us all their results, and have been most liberal in assisting us in every possible way.

16. As regards our own work we have, in an earlier paragraph, explained the general scope of our investigations.

Throughout our inquiry we have endeavoured to gain such knowledge as would enable us to pass from the stage of broad qualitative observation to one of exact quantitative statement, but in regard to many matters this transition is not at present practicable, and, therefore, we can only comply in general terms with the terms of reference which directed us to state "by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined."

The circumstances of different places are of endless variety and there are many varieties of treatment, any one of which will be successful, if properly carried out. The main question to be determined in each case is which of these methods will be cheapest, having regard to the local circumstances.

We propose to discuss various methods of disposal in some detail, and then to indicate, in broad terms, the considerations which should be borne in mind in the selection of a method of treatment for any particular case.

STRENGTH OF SEWAGE AS AFFECTING PURIFICATION.

17. The composition of different sewages varies to a large extent, and it is important to consider how strength of sewage, as affecting purification, may be measured. The amount of filtration necessary to produce an effluent of any given standard of purity varies, to a wide extent, with different sewages.

The variations in strength of the sewage of different towns depend chiefly on the amount and nature of the water supply; the extent to which the houses are provided with water closets; whether a separate system of sewers is provided for storm waters; and what trade effluents (if any) are admitted into the sewers. Dr. Fowler has pointed out that a fairly accurate idea of the strength of sewage, as affecting purification, may be arrived at by measuring the number of gallons of sewage per head per day arriving at the outfall and making allowance for the other factors, while other witnesses have suggested that the usual tests, such as "oxygen absorbed", are sufficient. 22735.

18. Where, however, a more exact measure of strength is needed, we are inclined to think not only on theoretical grounds, but also as the result of experience, that this can at present best be obtained by ascertaining the amount of dissolved oxygen taken up during the complete, or practically complete, oxidation of the organic and ammoniacal matter in the sewage. 25578.

The purification of sewage is to a large extent a process of indirect oxidation through the agency of bacteria, and one of the chief things required to be known about any particular sewage is how much oxygen is required for its complete oxidation. The rate at which the sewage will take up oxygen is also a factor of importance, in that it furnishes information as to the character of the organic matters.

The dissolved oxygen test is a biological process, and it differs from the ordinary tests—such as oxygen absorbed from permanganate—in that it takes account of practically the whole of the organic matter, and not merely that of a particular kind.

The amount of oxygen which a sewage can take up is, however, only an approximate measure, for purposes of purification, of its strength, as some constituents of sewage are oxidized by filters or land more readily than others, and the proportion which they bear to the total organic matter varies largely in different cases.

19. To determine the amount of oxygen which a sewage requires for its oxidation, a definite quantity of the sewage is allowed to remain in contact with a known excess of oxygen until it is completely oxidised, and the oxygen remaining over is then measured. This can be done either:

(*a*) By diluting the sewage largely with good tap water, estimating the oxygen in solution in a portion of the mixture, and allowing the remaining portion to stand in a bottle which is filled completely and shut off from all access of air. At least two months must be allowed for this, after which the oxygen remaining in solution is determined. The difference represents the oxygen used up.

(*b*) By keeping the sewage, without diluting or diluting only very slightly, continuously aerated in a bottle containing a measured excess of air. Dr. Adeney, who has suggested this plan, has found it to be very much more rapid than the first.

20. A serious disadvantage in the use of the dissolved oxygen test as a measure of the strength of sewage is that it requires, even with the more rapid method suggested by Dr. Adeney, a comparatively long time to oxidize the organic matter completely by dissolved oxygen. From the results of a considerable number of laboratory experiments with method (*a*), we thought that a period of about two months might be generally taken as sufficing for the oxidation of nearly all the oxidisable matter, excluding (to some extent,

at least) cellulose and fat. Later results, however, appear to show that this may be too short a time under ordinary conditions of experiment. Though we have not made enough observations on the point to speak definitely, we are satisfied that the oxidation of cellulose and fat in diluted sewage, under the aerobic conditions of our experiments and at ordinary temperature, is slow*. In practice, however, there are but few instances of the treatment of *crude* sewage on biological filters, and the amounts of cellulose and (probably) of fat which are present in the liquids usually treated (settled sewage, septic tank liquor, and precipitation liquor) are relatively small.

By method (*b*) and by making use of a mechanical shaker attached to a suitable gas apparatus, Dr. Adeney† succeeded in oxidizing strong septic tank liquor by means of atmospheric oxygen, without any dilution with water, while he followed the course of the reaction by determining at different intervals of time the quantity of oxygen required by known volumes of the liquor. In this way he reached the nitrification stage of the process in twelve days. The method is thus a great advance, as regards time required, upon the dilution method.

Recently Dr. Adeney has invented an ingenious apparatus for carrying out the dissolved oxygen absorption test, by which the rate of absorption of oxygen as well as the total amount of oxygen taken up can be readily measured. It is described on p. 438 of Appendix VI.

21. With a view to ascertaining whether the dissolved oxygen absorption test bears any more or less constant ratio to other and more rapid tests, Dr. McGowan, our chemist, has made a number of observations.

He gives figures to show that the amount of dissolved oxygen which a sewage would take up during oxidation can be arrived at, with a fair degree of accuracy, by a calculation based on the " oxygen absorbed " figure and the figures of analysis of the ammoniacal and organic nitrogen.

A copy of Dr. McGowan's Memorandum is printed in Appendix IV.: the following extract shows the formulæ which he suggests:—

"By applying the results given in Table A it would appear that the relative 'strength' of a sewage liquor can be arrived at rapidly, with a fair degree of accuracy, by estimating the ammoniacal and organic nitrogen and the 'oxygen absorbed" from strong acid permanganate *at once* and *in 4 hours* at 27°C. (80°F.), and afterwards making use of one of the following alternative formulæ:—

(1)		
Column 9.	For *Sewages.*	(Ammon. + Organic N.) × 4·5 + (Oxygen abs. in 4 hrs. × 6·5).
	For *Septic Tank Liquors.*	,, ,, ,, + (,, ,, × 6·5).
	For *Precipitation Liquors.*	,, ,, ,, + (,, ,, × 6·0).
(2)		
Column 10.	For *Sewages.*	(Ammon. + Organic N.) × 3·0 + (Oxygen absorbed in 4 hrs. × 8·0).
	For *Septic Tank Liquors.*	,, ,, ,, + (,, ,, ,, × 8·0).
	For *Precipitation Liquors.*	,, ,, ,, + (,, ,, ,, × 7·5).
(3)		
Column 8.	For *Sewages,*	(Ammon. N. + 4·5) + (Oxygen absorbed in 4 hrs. × 8·0).
	For *Septic Tank Liquors.*	,, ,, + (,, ,, ,, × 7·5).
	For *Precipitation Liquors.*	,, ,, + (,, ,, ,, × 7·5).

"The variations in the individual ratios given by the same kind of sewage liquor in Table A are too great to allow of this method of arriving at their 'strengths' being more than approximate. Probably the variations would have been less marked if all the long aerations had been carried out in mercury-jointed bottles, and if the small quantities of gases evolved had been allowed for. Further experiments will, however, settle the point."

* One part of cellulose, by weight, requires only 1·2 parts of oxygen for its complete oxidation; one part of fat requires nearly 6 parts of oxygen. Tri-palmitin $C_3H_5(OC_{16}H_{31}O)_3$ is taken here to represent fats generally.

† The Pollution of Estuaries and Tidal Waters. Report to the Royal Commission on Sewage Disposal, by Professor Letts and Dr. Adeney, p. 101 *et seq.* See Appendix VI.

As regards Dr. McGowan's suggestion, we consider that until the method of calculation which he proposes has been compared with the results of direct experiment on a larger number of *different* sewages, no statement can be made as to its precise accuracy. We have, however, found it convenient to use the method in the preparation of this Report in order to bring results at different places into line.

In later sections we shall frequently define the strength of a sewage or sewage liquor by a number. This number is intended to represent the number of parts, by weight, of dissolved oxygen which 100,000 parts of the liquid would take up during the oxidation of the oxidizable matter contained in such liquid. It will not, however, have been arrived at by direct experiment, but by a calculation, according to the first of the formulæ suggested by Dr. McGowan, and it must therefore only be regarded as approximately representing what it is intended to represent.

22. As bearing on the question of strength of sewage as affecting purification, we may refer to our experiments at Accrington.‡

A double contact bed plant filled with rather fine and graded material was provided in duplicate. On one set of contact beds, septic tank liquor was treated at the rate of 80 gallons per cube yard per day; on the other set, the same septic tank liquor diluted with an equal volume of tap water was treated at double the rate. The percentage purification was slightly greater in the case of the contact beds treating the weaker liquor.

Two exactly similar percolating filters, 9 feet deep, filled with coarse material, were also provided.

On one filter, septic tank liquor was treated at the rate of 100 gallons per cube yard per day; on the other filter, the same septic tank liquor diluted with an equal volume of tap water was treated at double the rate. In this case the percentage purification was slightly greater with the filter treating the stronger liquor.

The differences in the percentage purification were, however, in both plants so small that we think it may be taken broadly that, within ordinary limits of concentration and volumes treated, it is the amount and nature of the organic impurity present which mainly determine in practice the ease or difficulty of purification; in other words, that, within practical limits, mere dilution does not affect the size of the filtering plant which is necessary. Of course if the dilution is so great as to cause water-logging of the filters, their purifying power would be seriously diminished, and this statement would not hold good.

The Accrington experiments are dealt with more fully on pages 110 to 117 of this Report.

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‡ *See* Appendix IV. for a full account of these experiments.

PRELIMINARY PROCESSES FOR THE REMOVAL OF SUSPENDED MATTERS.

General Observations.

23. The evidence which we have received and our own experience show that it is generally more economical to remove from the sewage, by a preliminary process, a considerable proportion of the grit and suspended matter, before attempting to oxidize the organic matters on land or in filters.

It is true that at Leeds, Sutton, Hampton, Hendon (the Ducat filter), Market Drayton (the Ducat filter), and elsewhere, crude sewage has been satisfactorily purified in filters with almost complete absence of nuisance, but at most of those places, this plan has been abandoned because of the rapid choking of the filters.

As regards the treatment of crude sewage on filters, we have ourselves made detailed observations at the following places :—

Hampton.	Maidstone.
Hendon.	Newton-le-Willows.
Little Drayton.	Withnell.

Reports on these observations are published in Appendix III.

There are also many cases in which crude sewage has been passed over land, but the evidence shows that land treatment of crude sewage is liable to give rise to nuisance by the accumulation of solids on the surface of the land. Moreover, in some cases these solids are apt to form an impervious layer which interferes with the aeration of the soil, and so impairs the efficiency of the treatment.

Screening.

24. On arriving at the works the sewage is usually passed through coarse screens for the purpose of removing the grosser suspended matters, such as sticks, cloths, paper, corks, etc.

The removal of such suspended matters is almost essential where the sewage has to be pumped, and in other cases it is usually considered an advantage.

Although the amount of suspended matter which is removed by coarse screens bears only a small proportion to the total suspended matter, the screenings have some manurial value, and there is usually no difficulty in getting farmers and others to take them away.

The screens in use are of various kinds, and some are provided with automatic apparatus for clearing them.

Experiments with fine screens were carried out at Leeds,* with a view to ascertaining whether it was practicable to remove a large proportion of the total suspended solids in this way.

With a screen of a mesh of 30 to the inch, however, rather less than 10 per cent. of the total of the suspended matters was removed.

The use of fine screens is always attended with difficulty as they choke readily, and the experience of Leeds seems to show that where tank treatment is provided as a preliminary process, the cost of fine screens would not be justified.

In the circumstances obtaining at Birmingham, Mr. Watson prefers not to screen the sewage, but to allow the whole of the suspended matter to flow, with the sewage, to the first sludge tanks. The sludge itself is screened, to remove the grosser solids, before it is disposed of on land.

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* Report on experiments in Sewage Disposal, June, 1905, by Col. T. W. Harding and Mr. Harrison.

Grit or Detritus Tanks.

25. Most of the witnesses whom we have examined favour the removal of the heavy suspended matters, such as grit or road detritus, as a first operation, and our own observations have shown that in most circumstances it is desirable to provide tanks for this purpose.

These tanks are usually designed so that the speed of flow will allow the mineral matters to settle out of the sewage, while the bulk of the organic suspended matters are carried forward.

The extent to which the heavy matters need be settled out of the sewage as a first operation depends in some measure on the subsequent treatment which is to be adopted.

Where septic tanks are to be used which will only be cleaned out at long intervals of time, fairly thorough preliminary settlement of grit is generally desirable. The removal of the sludge which has accumulated over a long period in a septic tank is, as a rule, a matter of difficulty, as the sludge is often so thick that it cannot be pumped unless sewage or water is mixed with it. Much mineral detritus in the sludge increases this difficulty.

We also consider that in the case of septic tanks from which a portion of the sludge will be removed periodically, preliminary settlement of the mineral detritus is, as a rule, desirable. Tanks to be used in this way are generally provided with sludge channels formed in the concrete floor. If the sludge to be drawn off contains much mineral detritus, it will not flow to the channels but will remain in heaps at the side.

In the case of a very small works (flow of sewage up to, say, 10,000 to 15,000 gallons per 24 hours) where septic tanks are used for the preliminary process, the provision of grit or detritus tanks which require constant sludging may necessitate more labour than would otherwise be the case, and in such circumstances it may be more economical to allow everything to go forward into the septic tank. Although the presence of the mineral detritus in the general tank sludge would make the sludging of the tank a more difficult operation, the saving of labour between the intervals of sludging would probably more than balance the extra cost of removing the sludge.

Where precipitation or sedimentation tanks are to be used, and especially if the district is sewered on the combined system, it will, we think, generally be found better to settle out a considerable proportion of the mineral detritus before allowing the sewage to pass into the tanks. The necessity of giving thorough preliminary settlement of the grit is not, however, in these cases of so great importance, for the presence of grit in sludge renders the latter more amenable to pressing and drying.

Sedimentation Tanks.

26. All tanks are sedimentation tanks, but it is convenient to limit the expression to tanks in which the sewage is allowed to settle, without the aid of chemicals, and from which the sludge is frequently removed.

In some cases the tanks are allowed to stand full, and the supernatant liquid is drawn off by a floating arm. In other cases the sewage is allowed to flow through the tanks slowly, but continuously.

Quiescent Sedimentation.

27. Experiments which were carried out at Leeds and Sheffield showed that, with the sewages of those cities, quiescent settlement for two to three hours was sufficient to remove a large proportion of the suspended solids entering the tanks, and to produce a fairly good tank liquor.

No precise rule, however, can be laid down as to the period of quiescence which is required to effect a given reduction of the suspended solids.

Certain kinds of sewage contain more solids which settle very slowly, than other kinds.

For example, a large proportion of the solids in sewages which contain brewery or tannery waste, or wool scouring liquor, are difficult to settle.

To maintain this form of settlement in a highly efficient condition, the deposit in the tank must be removed after every first or second filling.

Continuous Flow Sedimentation.

28. We have had experience of this method of sedimentation at Clifton, Halton, Oswestry, and Dorking. The following table shows the settlement effected at these places:—

Place.	Shape of Tank.	Dimensions of Tank.	Time allowed for settlement.	Rate of flow per minute in inches.	Solids (in parts per 100,000) reduced from
Clifton - -	Rectangular	39′ × 5′ × 4′.	5·3 hours.	1· 7″	49 to 24.
Halton - -	„	25′ × 12′ × 6′.	15·5 „	0·66″	17·7 to 10·7
Oswestry - -	„	70′ × 15′ × 4′ 6″.	4·1 „	3·40″	32·0 to 15·8
Dorking - -	„	18′ 6″ × 4′ 6″ × 4′ 9″.	11·9 „	0·31″	20·8 to 10·1

The amount of settlement does not depend alone on the period of flow, but also on various other factors, such as the shape of the tank, the nature of the suspended matter in the sewage, and the length of time during which the tank is used without being cleaned.

If the tank is not cleaned out frequently, the deposited sludge begins to ferment and the gas produced carries suspended matter with it, as it rises to the surface of the liquid.

As a general rule, if the filters to be used are constructed of fine material, on which it would be undesirable to put a large amount of suspended matter, we consider that the period of flow should be from 10 to 15 hours, and that the tanks should be cleaned out at least once a week.

Before either kind of sedimentation is adopted, the nature of the suspended matter in the sewage which is to be dealt with, and the rate at which it settles, should be considered.

Should Sedimentation Tanks be used in series or in parallel?

29. It would usually be more advantageous to use continuous flow sedimentation tanks in parallel than in series, for the following reasons:—

With tanks of ordinary dimensions, the minimum rate of flow is obtained where the tanks are used in parallel.

As a rule, after a certain percentage of the suspended solids has settled out of a sewage, little further advantage is gained by continuing the same tank treatment, the suspended solids remaining in the supernatant liquid being of low specific gravity, and depositing very slowly unless quiescent settlement is given. In practice, therefore, so soon as this maximum quantity of solids is settled out as a result of continuous flow settlement, little advantage is obtained by passing the liquid through another tank at a similar rate.

If sedimentation tanks are used in series, there is a natural tendency to allow the last tank in the series to run too long without being cleaned out. The result in such a case is that the sludge, lying at the bottom of this tank, even though small in amount, begins to ferment with the formation of gas bubbles, which carry suspended matter up into the liquid.

There is rather more difficulty in cleaning tanks which are used in series than those used in parallel, owing to the fact that the first tank in a series is usually found to contain very thick sludge, which may, in some cases, have to be mixed with sewage before it can be got to flow into the sludge main; while in the last tank the sludge is very thin and watery. At a large works, however, where there are special facilities for removing and dealing with dense sludge, such as would accumulate in the first tank, this difficulty would not be serious.

Our experience with continuous flow settlement tanks used in series has been obtained chiefly at Halton, and, with continuous flow settlement tanks used in parallel, at Oswestry and Shipley. As the same arguments apply to the settlement of precipitated sewage, however, we may also adduce the results of our observations at Kingston, Maidstone, and Hendon, for the use of tanks in series, and at Horfield, for the use of tanks in parallel.

It is desirable to use quiescent settlement tanks in parallel, in order that the period of actual quiescent settlement (*i.e.*, apart from filling or drawing off) should be as long as possible.

Nuisance.

30. Settlement of sewage by sedimentation does not give rise to serious smell during the time the tanks are actually at work. When the tanks are sludged, there is considerable smell, and since tanks used for quiescent settlement have to be sludged more often than those in which there is a continuous flow, there is more liability to recurring nuisance in the former case.

In the case of tanks used for settling domestic sewage, there is only slight local smell during the process of settlement. We have had practically no experience of the sedimentation of sewage containing brewery or tannery refuse in quantity, but in such cases the smell would, no doubt, be markedly increased.

Septic Tanks

31. The notion that the solid matter of sewage would be digested by passing the sewage through a sealed tank is by no means novel, but it does not appear to have had any extensive practical application until Mr. Cameron, who held the office of City Surveyor of Exeter, proposed the adoption of the "septic tank treatment" for that city.

At that time it was claimed that the septic tank possessed the following, among other, advantages:—

That it solved the sludge difficulty, inasmuch as practically all the organic solid matter was digested in the tank.

That it destroyed any pathogenic organisms which there might be in the sewage.

That sewage which had passed through a septic tank was more easily oxidized than sewage from which the solids had been allowed to settle, either with or without the aid of chemicals, in tanks which were frequently cleaned out.

32. As regards the first of these claims, it is now clearly established that, in practice, all the organic solids are not digested by septic tanks, and that the actual amount of digestion varies to some extent with the character of the sewage, the size of the tanks relative to the volume treated, and the frequency of cleansing.

At Huddersfield, Mr. Campbell estimated that about 38 per cent. of the solids were converted into gas or digested; at Leeds, Mr. Harrison put the figure at about 30 per cent.; at Manchester, Dr. Fowler says that possibly, though not certainly, about 25 per cent. of the total suspended matter is digested or converted into gas; at Sheffield, Mr. Haworth puts the digestion at 32·9 per cent., while at Birmingham, Messrs. Watson and O'Shaughnessy say that the figures available indicated a digestion of not more than 10 per cent. of the suspended matter entering the tanks. 21,633 21,994 22,923 23,611 24,985

From careful observations, extending over two years, which we made at Exeter and Ilford, we found that, without allowing a correction for colloidal matters, the digestion at Exeter was about 25 per cent., and at Ilford about 30 per cent.

The sewages of both places were domestic in character: the Ilford sewage was of average strength ; and the Exeter sewage about two-thirds as strong. In each case the tank was sufficient to enable it to hold a day's (24 hours) flow, and no sludge was removed from either tank during the experiment. A detailed report of the experiment is contained in Appendix IV.

33. As regards the second claim, we find as a result of a very large number of observations that the sewage issuing from septic tanks is, bacteriologically, almost as impure as the sewage entering the tanks.

34. As regards the third claim, the evidence which we received was conflicting. Some witnesses stated that septic tank liquor was more easily treated than sewage from which the solids had been settled, either with or without the aid of a precipitant, while others expressed a contrary view.

The point is one of great importance in the purification of sewage, and we therefore thought it desirable to investigate it somewhat exactly.

After visiting several places, the Dorking sewage was selected as a suitable domestic sewage with which to experiment, and the Dorking Urban District Council were good enough to grant us the requisite facilities for making the experiment at their works.

For the purpose of the experiment, three identical percolating filters were constructed. One was fed with settled sewage, one with sewage which had been subjected to chemical precipitation, and one with septic tank liquor.

35. The experiment, which was under the supervision of our own resident chemist, Mr. Eric H. Richards, and was carried on for over a year, conclusively proved that in the case of an ordinary domestic sewage, such as that at Dorking, septic tank liquor is not more easily oxidized on its passage through filters than the other liquids.

The experiment is fully reported on by Mr. Richards in his Report, which is published in Appendix IV.

The results of careful experiments previously carried out at Rochdale by Mr. Platt, at Leeds by Mr. Harrison, at Huddersfield by Mr. Campbell, and at Sheffield by Messrs. Wike and Haworth, at all of which places the sewage contains trade effluents from manufacturing processes, agree with our Dorking results.

36. It must, therefore, be said that some of the more important claims which were originally advanced in favour of septic tank treatment have not stood the test of experience. At the same time, we think that in certain circumstances the adoption of this method of treatment, as a preliminary process, is efficient and economical.

Suspended Solids issuing from Septic Tanks.

37. The settlement of the suspended solids in septic tanks is not usually very thorough, and the evidence shows that at many places the liquor issuing from the tanks contains on the average from 15 to 20 parts of suspended solids per 100,000.

At the places which we have had under observation the average figures were as follows :—

SEPTIC TANKS.

Name of place.	Character of sewage.	Suspended solids in original sewage. Parts per 100,000.	Suspended solids in tank liquor. Parts per 100,000.		Time of passage through tanks.
			Average.	*Remarks.*	
Accrington - -	Strong domestic sewage	38·93	19·40	14·3 shortly after sludging	Once in 42 hours.
Andover - - - -	Domestic, containing some brewery refuse.	15·80	11·10	8 months after incomplete sludging.	Once in { 19·3 hours (dry weather flow). 13·1 hours (max. flow).
Caterham - - - -	Exceptionally strong domestic	42·10	22·2	1 month after sludging	Apparently 48 hours' flow, when 3 out of the 4 hourly sets were drawn.
Exeter (Main Works) -	Strong domestic	37·2	12·50	18 months after sludging	Once in 11·5 hours (dry weather flow).
Exeter (St. Leonards) -	Weak domestic	26·10	8·40	12 months after complete sludging.	Once in { 17·8 hours (dry weather flow). 8·6 hours (maximum flow).
Hartley Wintney - -	Domestic, with a considerable proportion of brewery refuse.	{ 20·10 (dilute winter sewage) 32·7 (dry summer sewage) }	15·10	After 3½ years without sludging	Once in 31·7 hours (dry weather flow).
Guildford - - - -	Strong domestic, containing a large proportion of brewery refuse.	42·1	15·9	Tank full of sludge	Once in 36·7 hours.
Knowle - - - - -	Domestic	19·40	8·42	——	Once in { 15·2 hours (dry weather flow). 3·2 hours (max. flow).
Prestolee - - - -	Weak slopwater sewage	5·42	3·17	After 4½ years without sludging	Once in 22 hours (dry weather flow).
Rochdale - - - -	Strong manufacturing sewage, containing large quantity of wool scourings, etc.	36·70	5·30	Tank in use for only 3 months	Once in 30 hours.
Slaithwaite - - -	Dilute domestic (mainly slopwater)	10·70	7·10	After 5½ years without sludging	Once in 13·6 hours (dry weather flow).
York - - -	Weak domestic	21·2	5·3	Two tanks, one in use 18 months and the other 6 months.	Once in 26 hours.

It must also be observed that it is generally impracticable to maintain the amount of suspended solids issuing from a septic tank at an approximately uniform level for any length of time ; and, that the amount has a tendency to increase seriously as time goes on.

For example, at Burnley it was found that the suspended matter varied from 15 parts per 100,000, after a few weeks' working, to 35 parts per 100,000 at the end of six months ; at Huddersfield the amounts were 6·6 parts per 100,000 at the commencement and 23·3 parts per 100,000 at the end of eleven months ; at Leeds, from January to June, 1903, starting with a perfectly clean tank, the suspended solids averaged 12·2 parts per 100·000, and from July to December, 1904, the average was 24·1.

The variation in the amount of the suspended solids in the tank liquor increases the difficulty of maintaining the effluent from the filters at a constant level of purity, and the amount of tank liquor which can be properly dealt with on the filters tends to decrease as the amount of the suspended solids in the tank liquor increases.

Cleansing of Septic Tanks.

38. There is no doubt that the longer a tank is run without cleaning, the less *volume* of sludge there will be per million gallons of sewage treated. Digestion, of course, plays some part in this, but only a small part compared with the settling together of the finely divided septic sludge lying at the bottom of the tank. The sludge from a septic tank which is cleaned out at short intervals of time may contain something like 90 to 95 per cent. of water, while, if the tank is allowed to run for, say, two years, the water in the sludge may be only 80 to 85 per cent., or even less. It is obvious that this makes a great difference in the volume of the sludge to be dealt with, provided that it can be removed from the tank in the semi-solid form and without having to be mixed with sewage or water to make it run through the valves.

There is also evidence to show that sludge which has remained in a tank for a long period, say, a year or more, is in some cases less offensive than sludge which has been there for only two or three months. At Birmingham, Leeds, Exeter, and other places this was found to be the case, though, on the other hand, at Guildford, where there is a considerable amount of brewery waste in the sewage, the septic sludge had a very offensive smell when removed from a tank which had been in operation for a period of twelve months.

39. From the point of view of sludge disposal alone, it would be generally advisable to allow septic tanks to run for considerable periods of time before cleaning out, either wholly or partially. There are, however, two other important considerations to be taken into account, viz. :—

The amount of suspended matter issuing in the tank liquor, which greatly increases as time goes on, and

The fact that at a large sewage works it would usually be less easy to deal with very large quantities of sludge at long intervals of time than with smaller quantities at short intervals.

Constant conditions as regards the amount of suspended solids in the liquor issuing from the tank should be aimed at, and from this point of view frequent partial removal of the solids would usually be desirable ; but our experience points to the conclusion that there can be no definite rules as to how long a septic tank should be run without cleaning, and that it must be left to the manager of each works to see that the suspended solids issuing from the tank do not increase to such an extent as to have an injurious effect upon the filters or upon the quality of the filtrate. The point at which injury to the filters or deterioration of the filtrate will occur will largely depend upon the nature and strength of the sewage, the kind of filter used, the size of the material in the filter, and the rate of filtration. At Accrington, for instance, something like fifteen parts of suspended matter in the septic tank liquor can be put upon the coarse percolating filters, without any danger of clogging, whereas at Manchester and Burnley, this would be too much for the contact beds.

Again, the successful working of some forms of fine percolating filter (*e.g.*, that at Friern Barnet), depends upon the time allowed for the drying of the sludge on the surface of the material between two applications of tank liquor. A tank liquor containing, say, 10 parts of suspended matter per 100,000, might be conveniently treated on a filter of this kind, if the delivery were made once every three days; but if it were made once every day, the sludge caught on the surface of the filter would probably not have dried sufficiently to allow of its being scraped off before the next delivery was made.

40. Although the point is not one in regard to which any general rules of a precise character can be laid down, we are inclined to think that in the case of small sewage works, constructed to serve populations of, say, 100 to 10,000, it would be best that septic tanks should be allowed to run, without being cleaned out, so long as the suspended matter in the tank liquor showed no signs of affecting the filters detrimentally, provided that the tanks were never allowed to become more than one-third full of sludge.

In the case of a sewage works constructed to serve populations from 10,000 upwards, we think it would probably be advisable partially to clean out septic tanks at short intervals of time, care being taken as far as possible to remove only the best digested portion of the sludge.

41. With regard to the question whether it is advisable *entirely* to remove the sludge from septic tanks when these are cleaned out, the evidence and our own observations seem to show that this is not advisable. Experiments at Leeds, Rochdale and Dorking have shown that the changes which sewage liquor undergoes in a septic tank are of minor importance as regards subsequent filtration, but the following considerations must be borne in mind :— Cameron, 1902; Harrison; Campbell; Valentine; Wilkinson; Raymond, Ross and Pickles; Watson; Harding; Fowler.

In a septic tank which is to be cleaned out there is always a considerable amount of sludge which has had little time to undergo digestion. If possible, therefore, this part of the sludge should be left in the tank.

One of the main uses of a septic tank is that it has the effect of equalising the sewage as regards strength, and of keeping the character of the liquor uniform.

If a septic tank is cleaned out completely, some weeks may pass before the fermentation of the sludge is in full progress again. It was found, at Birmingham, that, if some of the sludge is left in a septic tank at the time of cleaning, fermentation is hastened when the tank is re-started. At Rochdale, Mr. S. S. Platt has shown that the same effect can be produced by filling a clean and empty tank with septic liquor (from another tank) before any fresh sewage is allowed to pass into it.

Where sludge is removed from septic tanks at long intervals of time, and especially where it is disposed of by burial in the ground, it is of great importance to carry out the operation in dry weather. The success of the plan of disposing of the sludge by burial in the ground depends very largely upon the rapidity with which the sludge can be covered over in the trenches, and this is governed by the state of the ground and the atmospheric conditions prevailing at the time.

Rate of Flow through Septic Tanks.

42. For the reasons which we have already given we consider that the main objects in passing sewage through septic tanks must be looked upon as being :—

The settlement of the suspended matter in the sewage ;

The digestion of as much sludge as possible ; and

The equalisation of the sewage as regards strength.

43. The most advantageous rate of flow, therefore, is that which gives the maximum settlement and the maximum digestion of sludge, without producing any serious nuisance from smell. It is impossible, however, to lay down any given rate or rates of flow through septic tanks for all sewages, for the following reasons :—

The suspended matter in sewage differs as regards ease of settlement and rate of fermentability at different places. The suspended matter in a strong slopwater sewage, for instance, settles more easily and takes longer to putrefy than the suspended matter in a strong domestic sewage derived from water-closets.

The degree of settlement depends also upon the form of tank adopted. The passing of a sewage through a Dortmund tank, for instance, would no doubt give better settlement than would be the case if a plain rectangular tank were used, but there would probably be less digestion of the sludge.

The qualities necessary in the septic tank liquor may vary at different places. At one place where septic liquor was to be treated upon percolating filters of coarse material, a larger quantity of suspended matter might be allowed to pass away in the liquor, without danger to the filters, than at another place where the liquor was to be treated upon fine-grained filters. Again, where it was of the utmost importance to have as little sludge to deal with as possible, and where the filters could be washed and re-made cheaply, the digestion of the sludge would be of greater importance than the settlement of the suspended matter ; whereas, at another place where ample facilities for dealing with sludge existed and where filtering material could only be obtained at high cost, the reverse would be the case.

The question of smell arising from the septic liquor during its distribution would also assume greater or lesser importance at different places. Generally speaking, very slow passage through the tank tends to increase the risk of nuisance from smell.

In a number of cases, owing to long sewers or to the use of the sewers for storage, the sewage is already in what is called a "septic" condition when it reaches the sewage works.

44. The rate of flow through a septic tank is consequently a matter in which the needs of each place require to be taken into account: but from general experience and a consideration of the evidence, we think it may safely be said that at few places should the sewage remain more than 24 or less than 12 hours in a septic tank. We think therefore, that the total tank capacity, excluding the stand-by * tanks for storm water, should be equal to the total daily dry weather flow. In designing a sewage works where septic tanks were to be adopted, never less than two tanks should be provided, and these should be so constructed that one tank alone could be used at a time. If better settlement became necessary, it might be found that this could be effected by using the tanks in series and adding small quantities of some precipitant to the liquid as it passed into the second tank.

21992. 45. Colonel T. W. Harding and Mr. W. H. Harrison carried out a series of experiments at Leeds, in which flows sufficient to fill the septic tanks in 12, 24, 48, and 72 hours were compared. The results showed that at that place, and using simple rectangular tanks, a rate of flow sufficient to fill the tank once in 24 hours was the best economic rate. Rates of flow slower than this gave only slightly better results as regards suspended matter in the tank liquor, and greater rates of flow brought out more suspended matter than it was thought desirable to send on to the filters. The experiments showed also that, if the flow was increased to a rate which filled the tank in 12 hours, the tank

* As to "stand-by" tanks see section dealing with treatment of storm water sewage, p. 204.

became choked with sludge before septic action was induced. The figures of analysis for the different rates of flow are given in the Report on Experiments in Sewage Disposal, City of Leeds, June, 1905, p. 66, as follows :—

Average Analyses referring to the effect of different rates of flow through open Septic Tanks.

Grains per gallon.	12 hours' flow.		24 hours' flow.		48 hours' flow.		72 hours' flow.*	
	Average analysis.	Per-centage reduction on crude sewage.	Average analysis.	Per-centage reduction on crude sewage.	Average analysis.	Per-centage reduction on crude sewage.	Average analysis.	Per-centage reduction on crude sewage.
Total solids - - - -	87·7	—	78·2	—	78·3	—	73·9	—
Suspended Solids - - -	19·2	52	11·4	71	10·9	73	9·9	76
Free Ammonia - - -	1·56	22	1·51	24	1·62	19	1·79	37
Albuminoid Ammonia - -	0·54	50	0·45	58	0·38	64	0·34	52
Oxygen absorbed in 4 hours at 80° F.	5·21	45	4·84	49	4·30	55	3·59	55

* Experiment at later date with weaker sewage.

46. Dr. G. J. Fowler, in his evidence relating to Manchester (May 12th, 1905 ; answer to Question 22773), says :—

"The most advantageous rate of flow is largely a matter of circumstances. It may be roughly taken from available experience that, with sewage of a strength of 40 gallons per head, about 24 hours' flow is desirable ; with a greater flow per head (the organic matter remaining the same) the rate may be correspondingly quicker and, with a less flow, less. Our knowledge on this subject is very imperfect. One may say, at any rate, that time must be given for settlement of the grosser solids and hydrolysis of the lighter suspended matter. Much, of course, depends on the length of travel in the sewer ; with a long travel the simple hydrolytic changes will already be almost complete, whereas, on the other hand, in latrine sewage the matter entering the tank may be practically in its original condition. There can be little doubt that the chief activity of the septic tank resides in the sludge and this needs to remain in the tank a very long time for thorough digestion to take place."

In answer to a further question (22979), Dr. Fowler stated that 24 hours' stay in the tank is the longest time he would allow.

Messrs. Watson and O'Shaughnessy, in their evidence relating to Birmingham (May 18th, 1905 ; answer to Question 24983), say :—

"The actual mean rate of flow through the first set of tanks is ·87 feet per minute, and through the second set of tanks ·32 feet per minute. This rate of flow is sufficient to set up most vigorous fermentation, and results in the destruction of very considerable quantities of organic matter, as evidenced by the copious evolution of gas from the tanks, and by the increase in the amount of 'free ammonia' in the tank liquor. A quicker rate of flow is detrimental to the septic action. The action is continued in the large conduit, the liquor taking something like 6 hours to traverse it. At the end of the conduit is a Dortmund tank installation, and here we have been able to make some interesting observations on the behaviour of this already highly septic liquor. We consider that septic treatment of Birmingham sewage for a period of at least 24 hours to be distinctly advantageous. At the present time this is as much as we can say definitely. The observed effect of additional septic treatment at the end of the conduit, in the Dortmund tank, is a great increase in the number of micro-organisms in the tank liquor. We consider that the rate of flow should depend very largely on the strength and on the character of the particular sewage to be dealt with—a stronger sewage requiring a longer time, and certain constituents of sewage being more easily broken down than others."

47. As regards the question whether it is possible to "over septicise" a sewage, several witnesses have stated that if sewage be kept too long in the tank, the amount of sulphuretted hydrogen produced is considerably increased, and some witnesses have expressed the view that too long a stay tends to impair the subsequent oxidation of the sewage during its passage through the filters.

Should Septic Tanks be closed or open?

48. We are not aware that any comparative observations have been made of the relative merits of closed and open tanks in the case of a domestic sewage, but comparative experiments have been carried out at Birmingham, Burnley, Leeds, and Manchester, which show that, as regards digestion of sludge and quality of tank liquor, the closed tank possesses no advantages over the open tank.

49. In cases, however, where it is important to avoid nuisance from smell, our experience shows that the closed tank is generally preferable.

At Exeter, Yeovil, Andover, Hartley Wintney, and Prestolee, where the tanks are covered in, the smell from the tanks themselves is almost entirely done away with.

At Accrington, Leeds, Rochdale, and Burnley, where the tanks are uncovered, there is, as a rule, appreciable local smell.

At Sheffield, the nuisance arising from the open (experimental) septic tank was so pronounced, that the men on the works raised strong objections.

At Gosport, a very serious nuisance arose from open septic tanks, which was almost entirely done away with by completely roofing over the whole of the tanks and channels at the works.

At Guildford and Carshalton it was found necessary to put a rough covering over the tanks. In both cases the smell was largely diminished as the result.

At Ilford, a substantial roof is now being provided, to diminish the smell.

On the other hand, at Birmingham and Manchester, very little smell arises from the open septic tanks. This is no doubt accounted for by the fact that the sewages contain manufacturing waste, iron salts in the case of Birmingham, and iron salts and tarry matter in the case of Manchester.

50. As regards closed tanks, we may observe that a roof somewhat hampers sludging operations, and further, that care is necessary to avoid explosion of the gas which accumulates under the roof. Serious accidents have been caused by the explosion of the gas in closed septic tanks.

Arrangements for removing Suspended Solids from Septic Tank Liquor before it is delivered to the Filters.

51. So far as we know, none of the attempts to screen septic tank liquor by passing it through a short depth of material have been successful. At Leeds a layer of fairly fine material was suspended in a small septic tank in such a way as to cause the liquor to pass through it before leaving the tank. The sludge lying at the bottom of the tank, in rising to the surface as a result of the evolution of gas completely clogged the bottom of this material and rendered it worse than useless for screening purposes.

At Ilford and Guildford layers of coarse material have been placed at the outlet sills of the tanks, but it appeared to us that this arrangement was ineffective.

At Chester a plan similar to that tried at Leeds was followed, but after a short time the straining material became seriously choked with the suspended matter rising from the bottom of the tank. The tank liquor consequently forcing its way to the surface through special channels, bringing a great deal of suspended matter with it.

52. At Salford, *precipitation liquor* is forced by head of water (5′ 6″) through a layer of medium to coarse gravel (½ to 1½ inches diameter), three feet in depth, laid at the bottom of some specially constructed tanks, called "Roughing filters." This plan undoubtedly removes a very considerable quantity of the suspended matter from the precipitation liquor. The area of these "Roughing filters" is, however, so small compared to the volume of precipitation liquor to be passed through them, that they can only deal with two-thirds of the flow, the gravel being almost always more or less clogged. About 8,000,000 gallons of precipitation liquor are, on the average, forced through the "Roughing filters" per day, and as the total area of filtering material in the tanks is only 2,040 square yards, the average rate of filtration is roughly 4,000 gallons per square or per cube yard per day. The material in the "Roughing filters" at Salford is washed by upward flow once in every six days, each filter working for five days and resting for one. Once a year the gravel is taken out and thoroughly washed. The average analysis of the Salford precipitation liquor, after it had passed through the roughing filters, is given by Mr. J. Carter Bell, as follows :— Bell, 23207.

1903 and 1904.

	Parts per 100,000.
Oxygen absorbed from permanganate in four hours	4·7
Alkalinity as calcium oxide	3·0
Free and saline Ammonia	1·95
Albuminoid Ammonia	·45
Nitrogen as Nitrates and Nitrites	·172
Chlorine	14·1
Suspended solids	2·9

Mr. Carter Bell stated that it has been found practicable at Salford to remove about 75 per cent. of the suspended matter of the precipitation liquor by means of the roughing filters. 23225

53. At Friern Barnet the precipitated sewage is given a two hours' contact in contact beds, called roughing filters, before it passes to the low level percolating filters. These roughing filters consist of medium-sized clinkers, four feet nine inches in depth. They remove a considerable portion of the suspended matter from the precipitation liquor, and may be looked upon as primary contact beds.

Straining tanks of a somewhat similar kind have been in use at Wimbledon for a number of years. In these, however, the filtering material (three feet in depth) rests on a false bottom, some distance from the bottom of the tank, and the sewage entering at the bottom of the tank flows upward through the material, a large portion of the suspended matter settling upon the floor of the tank underneath the material. The tanks are cleaned at short intervals of time. We believe the plan has been found to work well.

54. At Birmingham Mr. J. D. Watson interposes modified Dortmund tanks between the septic tanks and the continuous filters. He states that the average of nearly a year's observations shows that the Dortmund tanks removed 75 per cent. of the suspended matter from the Birmingham septic tank liquor. It must be remembered, however, in regard to this, that the Birmingham septic tank liquor contained a large quantity of suspended matter, the average amount for the year 1904 being 19·5 parts per 100,000. If Dortmund tanks were used for the settlement of tank liquors containing only small quantities of suspended matter (say five parts per 100,000), they would, we think, probably not be as efficient as some straining method such as that adopted at Salford. Watson, 25001.

55. A special tank has been designed by Dr. Owen Travis for the further removal of suspended and colloidal matter from the septic tank liquor at Hampton. We have not, ourselves, been able to make any observations on this tank.

Lime Precipitation following Septic Tank Treatment.

56. From some experiments which we have carried out at Dorking, we find that, by passing septic tank liquor through tanks of a size sufficient to hold about one quarter of the 24 hours flow, with the addition of from 2 to 3 grains of lime per gallon

to the liquor, the suspended solids are reduced from 8 to 5 parts per 100,000, a considerably larger quantity of the liquor can be purified per cube yard of filter, and the offensive character of the septic tank liquor is largely destroyed. The solids which are chiefly reduced are those which are volatile.

In many cases we think that this combination of septic tank treatment and precipitation will be found to be useful.

We have, however, had no experience of this arrangement on a large scale.

A small quantity of lime (about 1 grain per gallon) has been added to the septic tank liquor at Blackburn for some years with a view to aiding subsequent nitrification on the filters.

Chemical Precipitation.

57. There has been a tendency on the part of certain authorities to regard the chemical precipitation of sewage as an obsolete form of preliminary treatment. Our experience in no way justifies this view, and while we are not able to lay down any precise rules as to the particular cases in which chemical precipitation should be adopted, nor as to the relative cost and efficiency of the various precipitants which are available, we think it may be useful to state generally the results of our observations.

In the case of some sewages, which contain trade waste, it is almost essential to subject the sewage to some form of chemical treatment before attempting to oxidise the organic matter contained in it, and in the case of domestic sewages, chemical precipitation materially aids the deposition of the suspended solids, and facilitates subsequent filtration.

58. The actual amount of suspended solids remaining in the sewage after chemical precipitation varies according to a number of factors, but in the case of a domestic sewage, which is allowed to stand and settle for about 2 hours, it is practicable to produce a tank liquor containing from 1 to 4 parts per 100,000. Where the settlement is effected by continuous flow through the tank, at an 8-hour rate, the suspended solids may be brought down to from 3 to 6 parts per 100,000.

59. Excepting for the results relating to the Dorking sewage, which are given below, we have ourselves made no comparative experiments with regard to the relative cost and efficiency of the various substances used for the precipitation of sewage. We have, however, had some experience of the following precipitants, at works which have been under our observation :—

Lime.
Lime used in conjunction with Copperas (Ferrous Sulphate).
Lime used in conjunction with Alumino-ferric.
Alumino-ferric.
Alumino-ferric used in conjunction with blood, charcoal and clay (A.B.C. process).
Ferrozone.
Ferric Sulphate.
Sulphuric Acid.

At most of the works where domestic sewage has been treated, alumino-ferric has been the precipitant used. At some of the works, this precipitant has displaced ferrozone on the score of economy, and at Chorley, a considerable saving in cost (about £1 per million gallons) was effected by the manufacture of alumino-ferric upon the works.

At Dorking, although we did not experiment with equal aggregate quantities, the results of a series of experiments led us to the conclusion that a better result was obtained from a mixture of lime and alumino-ferric than from alumino-ferric alone.

The same conclusion, we believe, resulted from experiments made by Mr. Creer, the City Engineer of York, with the sewage of that city. Owing to its low solubility in water, lime requires automatic machinery for crushing and mixing before it can be effectively added to the sewage, and for very small sewage works its use would not be economical.

60. The following table gives a list of places where domestic sewage alone, or mixed with small quantities of trade refuse (as a rule brewery or tannery waste), is precipitated, the quantity of precipitant used, the dry weather flow of sewage, and the cost of the precipitant :—

TABLE I.

Place.	Precipitant.	Quantity of precipitant added (in grains per gallon). Based on the dry-weather flow.	Dry weather flow of sewage (treated by the precipitation process).	Character of Sewage.	Cost of precipitant per million gallons. Based on dry-weather flow.	Cost of precipitant per million gallons. Based on average daily flow.	Year.
Withnell -	Alumino-ferric -	15·7	*Gallons.* 10,000	Very strong	£ s. d. 5 6 0	£ s. d.	1903.
Radcliffe -	Alumino-ferric -	8·0	800,000			2 15 0	1902, 1903, 1904 & 1905.
Calverley	Alumino-ferric -	17·5	12,000	Very strong	2 10 0		1904.
Heywood -	Alumino-ferric -	8·0	630,000	Average strength.		1 7 6	
	Ferrozone - -	8·0	630,000			1 6 6	
Guildford -	Alumino ferric -	8·0	300,000	Very strong	2 2 0	1 4 5	1905.
Horfield -	Alumino-ferric -	5·0	40,000	Average strength.	1 10 0	0 17 6	1905.
Normanton -	Alumino-ferric -	6·7	175,000	Very strong	1 5 0		1902 to 1905.
Hendon -	Alumino-ferric -	5·5	950,000	Rather strong.		0 13 3	1906.
Chorley -	Alumino-ferric -	9·0	900,000	Average strength.		0 12 10	1902.
Royton -	Alumino-ferric -	2·22	367,500			0 6 7½	1906.
Buxton	Natural Iron-water - -	6–7 } 12 to 13	750,000			0 4 6	1906.
	Milk of Lime -	6 }					
Dorking -	Lime - -	5·6 } 9·1	200,000	Average strength.		0 15 8	1902, 1903 & 1904.
	Alumino-ferric -	3·5 }					
Friern Barnet	Lime - -	4·0 } 6·0	350,000		Lime 5/1 Alumino-ferric 7/7½ }	0 12 8½	
	Alumino-ferric -	2·0 }					
York - -	Lime - -	5·77 } 10·0	3,750,000	Average strength, or perhaps under average.		0 10 7	1904–1905.
	Alumino-ferric -	4·3 }					
Willesden -	Lime - -	3·85 } 9·31	1,930,950		Lime 1/5·38 Alumino-ferric 8/6·5 }	0 10 0	
	Alumino-ferric -	5·46 }					
Ealing -	Lime - -	4·0 } 6·0	1,000,000			0 6 9	Three years ending March, 1906.
	Alumino-ferric -	2·0 }					
Leyton -	Lime - -	15·0 } 22·0	3,000,000			3 11 0	1905–1906.
	Hanson's Sulphurous Powder - -	7·0 }					
Kingston -	Alumino-ferric, blood, charcoal, and clay (A.B.C. process) - - -	50·0	2,750,000	Average strength.		3 4 0	1902, 1903 & 1904.
Rochdale -	Alumino-ferric -	7·3 } 12·0	2,000,000	Very strong		1 8 7	1904–1905.
	Sulphuric Acid -	4·7 }					

NOTE.—It will be observed in the above table that at nearly all the places where lime is used as a precipitant the cost is relatively low. In regard to this, however, it must be stated that the figures of cost refer to the lime alone and do not include any charges with respect to the mixing. This might add, we think, from 2/– to 10/– per million gallons, according to circumstances.

61. In Table II. some of the places where we have made special observations are arranged in the order of percentage reduction in suspended matters. The figures for Withnell and Calverley are not included, the flow of sewage at those places being too small for proper comparison with the others.

TABLE II.

Place.	Precipitant.	Percentage reduction of suspended matter in the crude sewage.	Amount of precipitant added in grains per gallon. Based on dry-weather flow.	Actual amount of suspended matter left in the precipitation liquor (parts per 100,000).	Cost of precipitant alone per million gallons, based on the average daily flow.	Strength of precipitation liquor calculated on the basis suggested by Dr. McGowan, *see* p. 16.	Strength of crude sewage calculated in a similar manner.
					£ *s.* *d.*		
Kingston -	Alumino-ferric, blood, charcoal, and clay (A.B.C. process)	95	50·0	1·5	3 4 0	51	94
Horfield - -	Alumino-ferric	93	5·0	2·5	17 6 (approx.)	36	88
Chorley - -	Alumino-ferric	91	9·0	2·9	1 0 2*	50	106
Heywood -	Alumino-ferric	82	8·0	5·0	1 7 6	42 (approx.)	
Dorking - -	Lime -	82	9·0	7·0	15 8 (approx.)	about 60	95
Hendon - -	Alumino-ferric	80	5·5	5·5	13 3	58	110
Rochdale - -	Alumino-ferric and sulphuric acid	79	12·0	7·8	1 8 7	77	203
Guildford -	Alumino-ferric	75	6·5	14·6	1 4 5	171	194
Normanton -	Alumino-ferric	67	6·7	18·0	1 5 0	112	235
York - -	Lime and alumino-ferric	64	10·0	7·7	10 6	63	115

62. In comparing the costs in Table II., the influence which the suspended matter left in the liquor has upon the life of the filter-beds, used subsequently, must be specially borne in mind. For instance, according to their calculated strengths, the Kingston and Chorley precipitation liquors would require about equal filter areas, but the Kingston liquor only contains 1·5 parts per 100,000 of suspended solids against 2·9 parts in the Chorley liquor, and on the assumption that the rate of clogging is broadly in proportion to the amount of suspended matter in the liquor treated, if the two liquids were treated upon equal areas of *contact* beds, the filtering material would require washing twice as often at Chorley as at Kingston. The amount of colloidal matter is not great in either liquor.

The A.B.C. process is, undoubtedly, a very efficient form of chemical precipitation, and the dried sludge produced at Kingston is sold by the company.

In regard to all tank processes, it may be remarked that the greater the amount of suspended matter in the original sewage, the easier it is to obtain a good *percentage* reduction of the suspended solids.

* This figure applies to the year 1900, when the alumino-ferric was bought. At the present time (1906), when the alumino-ferric is made on the works, the cost of precipitation per million gallons is 12*s.* 10*d.*

63. In the experiments carried out under the Massachusetts State Board of Health, Mr. Allan Hazen compared lime, lime and ferrous sulphate, ferric sulphate and aluminum sulphate as used in various quantities upon the St. Lawrence sewage during the year 1889 (Report of experiments upon the chemical precipitation of sewage. State Board of Health, Massachusetts, 1890). The sewage was a very weak one.

The following are quotations from the summaries given in the Report by Mr. Hazen on these experiments:—

The Comparative Advantages of the Different Precipitants.

"It does not seem to me that the slight colour given by the use of iron "should be considered an objection in judging the merits of the different "processes. It should be remembered that when alum is used, a small "portion of the alumina is really present in the effluent, but being white, it "is not noticed as is a corresponding amount of iron.

"The lime process has little to recommend it. Owing to the large amount "of lime-water required and the difficulty of accurately adjusting the lime to "the sewage, very close supervision would be required to obtain a good "result, and, even then, the result is inferior to that obtained in other "ways.

"Precipitation by copperas is also somewhat complicated, owing to "the necessity of getting the right amount of lime mixed with the sewage "before adding the copperas. When this is done, a good result is obtained. "The amount of iron left in the effluent is much greater than the ferric "sulphate owing to the great solubility of ferrous hydroxide.

"Ferric sulphate and alum have the advantage over both lime and "copperas, that their addition in concentrated solution can be accurately "controlled, and the success of the operation does not depend upon the "accurate adjustment of lime or any chemical to the sewage. The results "with ferric sulphate have been, on the whole, more satisfactory than those "with alum. This seems to be due in part to the greater rapidity with "which precipitation takes place and in part to the greater weight of the "precipitate. It is probable, from the greater ease with which ferric "sulphate is precipitated, that it would give a good result, with a sewage "that was not sufficiently alkaline, to precipitate alum at once. It is quite "possible that the same process would not give equally good results upon "all kinds of sewage. Special sewages may require special treatment. "For this reason, and also on account of changes in the prices of the several "chemicals, it is impossible to say that one precipitant is universally better "than another."

Conclusions.

"Using equal values [*i.e.*, as regards price] of the different precipitants, "applied under the most favourable conditions for each, upon the same "sewage, the best results were obtained with ferric sulphate. Nearly as "good results were obtained with copperas and lime used together, while "lime and alum each gave somewhat inferior effluents. The range of these "results was, however, comparatively narrow; and it may be that with a "sewage of a different character, or with variations in the prices of the "chemicals, it would be advantageous to use copperas with lime, or even "alum. When lime is used, there is always so much lime left in solution "that it is doubtful if its use would ever be found satisfactory except in "case of acid sewage."

64. Various comparative experiments with precipitants have been made at a number of large towns and cities in this country; for instance, at Glasgow, amongst other experiments of the same kind, Mr. Thomas Melvin has experimented with sulphate of alumina and ferric sulphate, both used in conjunction with lime. The sulphate of alumina (44·5% $Al_2(SO4)_3$), which was bought, cost 33s. per ton, while the ferric sulphate (9% Fe), made upon the works, cost 11s. 3d. per ton. In each of the trials (which extended over long periods) 8 grains per gallon of the precipitant were used in conjunction with 4 grains per gallon of lime. We understand that ferric sulphate and lime always gave the better result.

Sir Thomas Wardle ("Sewage Treatment and Disposal") also obtained good precipitation results by the use of a mixture containing basic ferric sulphate as its chief ingredient.

Fowler, 22758. In his evidence relating to Manchester Dr. G. J. Fowler stated:—

"I have had experience with various chemicals, viz., lime and copperas, "ferric salts and alumino-ferric, but have not gone very exhaustively into "their various merits. Lime and copperas give a precipitate which readily "settles, and lime is useful where flushes of acid have to be neutralised. On "the other hand, their use requires constant and skilled supervision, and "is therefore less suitable for small works than alumino-ferric, where a given "quantity can be added from time to time and be left to dissolve in the "incoming sewage. Ferric salts I have not found to give so rapid pre-"cipitation as either the lime and copperas or the alumino-ferric. The "precipitate appears more finely divided than either of the others. More-"over, ferric salts, unless made on the works, are not readily obtained in "the quickly soluble and, at the same time, transportable condition. The "following are prices per ton delivered at or near Davyhulme, showing that "for equal weights, lime and copperas are undoubtedly cheaper than "alumino-ferric:—

"Lime	11s. 6d.
"Copperas	21s. 6d.
"Alumino-ferric	40s. 0d.
"Ferric sulphate	23s. 6d.

"These prices will, of course, vary in different parts of the country."

Watson 24968. Mr. J. D. Watson and Mr. F. R. O'Shaughnessy, in their evidence relating to Birmingham, stated:—

"Milk of lime added to the crude sewage was used as a chemical "precipitant for many years, and was totally discontinued in February, 1901. "During the last twelve months of this process the tank capacity at the out-"fall works consisted of two installations of tanks, which were worked in "series. The mean period of sedimentation in the preliminary tanks was "3½ hours, and in the secondary installation of tanks the mean period of "sedimentation amounted to 5½ hours, giving a total mean period of "sedimentation for the limed crude sewage of 9 hours. The flow of sewage "for the last twelve months of the process was estimated at twenty million "gallons per day. The proportion of lime added to the crude sewage was "12 grains per gallon, being the equivalent to a quantity of 15 tons 6 cwts. "dry lime used daily.

"The following analysis will indicate the effect of this liming process "upon the crude sewage:—

Year 1900.	Parts per 100,000.	
	Dissolved Solids.	Suspended Solids.
Crude Sewage	129·1	67·6
Preliminary Tank Liquor	138	16·3
Final Tank Liquor	133·2	4·2*

Harrison, 21979. Mr. Harrison, in his evidence relating to Leeds, stated:—

"Several precipitants have been tried upon the Leeds sewage in order "to obtain their relative values, but the question of cost has not been

* It must be borne in mind that the Birmingham sewage contains iron salts in considerable quantity, so these good results cannot be ascribed to the lime alone.

"considered. The most effective precipitant was a mixture of ferric salt and "lime, closely followed in merit by aluminum sulphate and lime. These two "precipitants were almost equally effective, and were followed in order of "merit by alum and lime, ferrous sulphate and lime, ferric salts, alum and "ferrous sulphate. The last was practically valueless."

Mr. Carter Bell in his evidence relating to Salford, stated:— Bell, 23218.

"We have tried many systems of sewage purification and combinations "of chemicals. The best and most economical results have been obtained by "the use of lime followed by salts of iron."

Mr. Bolton, in his evidence relating to Heywood, stated:— Bolton, 21107.

"I have tried various chemicals. Iron and alumina compounds have "been used under such trade names as alumite, kremnolite, ferrozone, "alumino-ferric, etc. Alumino-ferric is the best precipitant tried at "Heywood. With an addition of 8 grains per gallon, a purification of "62 per cent. is brought about. This equals £1 7s. 6d. per million gallons. "Ferrozone under the same conditions brought about a purification of 57 "per cent., equal to a cost of £1 6s. 6d. per million gallons. Thus, for 3·6 "per cent. reduction in price 8 per cent. less purification was obtained "by ferrozone."

65. Where the sewage, by reason of the discharge of large quantities of trade refuse, is of a special character, special precipitants have, of course, to be used.

At Bradford, where there is a very large proportion of wool-scouring refuse in the sewage, sulphuric acid is used as the precipitant, in order to separate the fat, which is afterwards extracted from the sludge.

At Rochdale, where on several days of the week, owing to the discharge of wool-scouring refuse, the sewage resembles that of Bradford, sulphuric acid is used to neutralise the alkali in the wool-scouring refuse *after* the precipitation of the sewage with alumino-ferric.

At Burton-on-Trent, where there is a largely preponderating quantity of brewery waste in the sewage, very large quantities of lime have to be added.

Ways of adding chemicals.

66. Chemicals are most effective in precipitating a sewage when they are added in the form of a solution.

In practice, however, the addition of a solution of precipitant to a sewage is not always so economical or effective as the use of the precipitant in a solid form, owing to the fact that it is advisable to vary the quantity of the solution with the varying strength of the incoming sewage—a matter of some difficulty at a small works.

At a large works, where the addition of the chemicals can be properly supervised, we should think that, with the exception of lime, all chemicals should be added in the form of a solution. Lime is best added in the form of milk of lime, as it is not very soluble in water, and its addition in solution, involves the use of large quantities of water or sewage.

At medium-sized or small works it is usually found best, for economy of labour, to add such precipitants as alumino-ferric or ferrozone in the form of a solid block, placing the block in the sewage channel so that the top of it projects above the level of the sewage. In this way the largest quantities of precipitant are dissolved at those times of the day when the flow of sewage is greatest.

67. At Horfield and Hendon we found a simple and effective way of adding alumino-ferric in the form of a solution. The quantity of precipitant required for about 24 hours was, each morning, put into a box with a false bottom, and the alumino-ferric was dissolved by allowing water to drip on to it. During the daytime, when the box was full of precipitant, and when the sewage was strongest, a larger amount of the alumino-ferric was delivered to the sewage, owing to the solution being then stronger than it was at night, when almost all the precipitant had dissolved away. Moreover, the dose could be varied at will by increasing the flow of water.

This plan appeared to us to be rather more effective than the method of placing blocks of the precipitant in the sewage channels, though that method is also in the main satisfactory.

We have had no experience of copperas used alone; in the cases that have been brought to our notice, it has been used along with milk of lime. In these cases it has usually been found best to add it after the lime.

Immediately after the addition of any chemicals the sewage should be churned up so as to produce a thorough mixture. This can be done effectively by some mechanical apparatus or by baffling boards.

Some Observations as to the Relative Cost of various Preliminary Processes.

68. Local conditions and circumstances must always be the first consideration in the selection of a process for the preliminary settlement of the sewage of any particular place, and it is not possible to give figures of cost which would apply generally.

We think, however, it will be useful to compare the various processes in common use in a hypothetical case in which we assume :—

That ample fall is available;
That the sewage is of a normal domestic character and of average strength;
That the flow of sewage is 1,000,000 gallons per day in dry weather;
That all tanks are of simple construction, and rectangular in shape.

The processes which we propose to compare are :—

Septic tanks;
Continuous flow settlement without chemicals;
Quiescent settlement without chemicals;
Continuous flow settlement with chemicals;
Quiescent settlement with chemicals.

Comparative Capacities of Tanks.

69. From our general experience and from a consideration of the evidence we think the various lengths of time required for settlement and the number of tanks may, for the purpose of this comparison, be those shewn in the following table:—

Preliminary Process (arranged in order of tank capacity).	Stay in Tanks.	Total Number of Tanks.	Number of Spare Tanks.	*Total Capacity of Tanks required (gallons).
Continuous flow settlement with chemicals	8 hours	8	2	444,440
Continuous flow settlement without chemicals	15 hours	8	2	833,333
Quiescent settlement with chemicals	2 hours	10	2	1,041,660
Quiescent settlement without chemicals	2 hours	10	2	1,041,660
Septic tanks	24 hours	6	1	1,200,000

* The tanks would be sufficiently large to deal with 3,000,000 gallons per day in times of storm.

Initial Cost of Tanks.

70. From these estimates of the total tank capacities, Mr. G. B. Kershaw, our Engineer, has prepared drawings for each preliminary process, from which he has taken out complete quantities, and prepared the following estimates :—

Preliminary Process (arranged in order of cost).	Constructional Cost of Tanks.
Continuous flow settlement with chemicals	£3,797
Continuous flow settlement without chemicals	£5,112
Quiescent settlement with chemical	£5,987
Quiescent settlement without chemicals	£5,987
Septic tanks (open)	£6,891

Cost of Chemicals.

71. Several different substances are used in practice for the precipitation of sewage, dependent to some extent on the kind of sewage to be dealt with. For the precipitation of domestic sewage of about average strength, however, alumino-ferric is by far the most common and we have adopted this precipitant in our hypothetical case. The average quantity of the precipitant used may be put at about 10 grains per gallon (or 14·3 parts per 100,000). The cost of alumino-ferric varies at different places; but taking it at £2 5s. per ton, the cost of chemicals work out at £523 15s. per year or £1 8s. 8d. per million gallons of sewage (dry weather flow).

Production of Sludge.

72. We think it may be taken that, on the average, domestic sewage contains about 35 parts of suspended matter per 100,000 in dry weather, and that 1,000,000 gallons of domestic sewage would, in dry weather, produce approximately 1 ton 11 cwt. of *dry* sludge, *i.e.*, sludge containing no moisture. Where the quantity of alumino-ferric added is not excessive, practically the whole of its alumina is thrown out of solution, and since there is considerable evidence to show that small quantities of dissolved or colloidal sewage matter are also precipitated, we may assume for the purposes of this argument that, in addition to the 35 parts of suspended matter in the sewage, something like 5 parts of additional solid matter* must be taken into account. We assume, therefore, that our hypothetical sewage, with its precipitant, contains $35+5=40$ parts per 100,000 of suspended matter as it enters the tanks. From this must be deducted the amount of suspended matter issuing in the tank liquor, and, from a large general experience, we estimate that the addition of 10 grains per gallon of alumino-ferric to our hypothetical sewage would produce a tank liquor containing on the average about 2·5 parts per 100,000 of suspended matter if quiescent settlement were adopted, and about 4·5 parts per 100,000 if continuous flow settlement were adopted. On this basis the dry solid matter left in the settling tanks as the result of these two preliminary processes would be as follows :—

	Parts per 100,000.
Chemical precipitation followed by quiescent settlement	$35+5-2\cdot5=37\cdot5$
Chemical precipitation followed by continuous flow settlement	$35+5-4\cdot5=35\cdot5$

73. With settlement of sewage without chemicals, we estimate that the quantity of suspended matter issuing in the tank liquor would be approximately 7 parts per 100,000 after quiescent settlement, and 10 parts per 100,000 after continuous flow settlement. The dry solid matter left in the tanks, therefore, would be :—

	Parts per 100,000.
Quiescent settlement, without chemicals	$35-7=28$
Continuous flow settlement, without chemicals	$35-10=25$

* Alumino-ferric contains roughly 50 per cent. by weight of $Al_2(SO_4)_3$. If the whole of the alumina were precipitated by the sewage 14·3 parts per 100,000 of alumino-ferric would thus give approximately 2 parts per 100,000 of dry Al_2O_3. To the alumina must be added the colloidal matter thrown down by the action of the alumino-ferric upon the sewage, and we have estimated this at approximately 3 parts per 100,000. The latter figure has, however, been obtained from a comparatively small number of analyses.

74. In the case of septic tanks the digestion of sludge must be taken into account, as well as the amount of suspended matter carried away in the tank liquor. The digestion of sludge from a domestic sewage may be put approximately at 30 per cent. of the total suspended matter entering the septic tank, and on the average the liquor issuing from the septic tank would contain 10 parts of suspended matter. On this basis, the amount of sludge left in the septic tank would be $35 - 10 - 10 \cdot 5 = 14 \cdot 5$ parts per 100,000.

75. The production of sludge in our five preliminary processes of settlement would, therefore, be represented by the following figures :—

Preliminary Process.	Sludge left in Tanks (in parts per 100,000).
Quiescent settlement with chemicals	37·5
Continuous flow settlement with chemicals	35·5
Quiescent settlement without chemicals	28·0
Continuous flow settlement without chemicals	25·0
Septic tanks	14·5

Taking the average percentage of water in the sludges generally at 90, we obtain the following figures for the production of wet sludge by each preliminary process per 1,000,000 gallons :—

Preliminary Process.	Wet sludge (90 per cent. water) produced per million gallons of sewage (dry weather flow).
Quiescent settlement with chemicals	17 tons
Continuous flow settlement with chemicals	16 „
Quiescent settlement without chemicals	12 „
Continuous flow settlement without chemicals	11 „
Septic tanks	6·5 „

Cost of Labour.

(*a*) Disposal of Sludge.

76. The various methods of disposing of sludge are not in every case suited to each kind of sludge. Septic tank sludge, for instance, is rather difficult to press, being usually greasy. For the purposes of comparison we have selected the plan of shallow burial in the soil, as this method is for practical purposes equally well suited for the disposal of the sludge from each preliminary process.

For the burial of 1,000 tons a year of wet sludge (90 per cent. water), we estimate that one acre of land with soil of good or medium quality is necessary. On this basis the following areas would be required for the burial of the sludge from the various preliminary processes :—

Preliminary Process.	Quantity of wet sludge (90 per cent. water) produced per annum.	Area of Land required.
Quiescent settlement with chemicals	6,205 tons	6·20 acres
Continuous flow settlement with chemicals	5,840 „	5·84 „
Quiescent settlement without chemicals	4,380 „	4·38 „
Continuous flow settlement without chemicals	4,015 „	4·01 „
Septic tanks	2,372 „	2·37 „

The trenching of this land and the covering of the sludge would probably require the whole time of two men in the case of the two chemical precipitation processes and the quiescent settlement process, and one man in the case of the continuous flow settlement process.

In the case of the septic tank process additional labour would only be required when the tanks came to be cleaned out, say, twice a year. On the assumption that the services of some six men would be required for a fortnight on these occasions, we estimate that this would involve a labour expenditure of about £30 per annum.

Taking labourer's time at 21s. a week, and including one-third of the manager's time at a salary of £130 per annum, the labour cost in connection with the sludge trenching would be as follows :—

Preliminary Process.	Cost of labour and Supervision in connection with the Disposal of Sludge on the Land.	
	Per annum.	Per million gallons of sewage (dry weather flow).
	£	s. d.
Quiescent settlement with chemicals	152	8 4
Continuous flow settlement with chemicals	152	8 4
Quiescent settlement without chemicals	152	8 4
Continuous flow settlement without chemicals	98	5 4
Septic tanks	73	4 0

(*b*) Working and Sludging of Tanks.

77. For the working and sludging of the tanks we estimate that the services of three men would be required in the case of the two chemical precipitation processes and in that of quiescent settlement, and of two men in the case of the continuous flow settlement process and the septic tank process.

Taking labourers' time at 21s. a week, and including one-third of the manager's time, at the salary of £130 per annum, we obtain the following figures :—

Preliminary Process.	Labour and Supervision in connection with Tanks.	
	Per annum.	Per million gallons of sewage (dry weather flow).
	£	s. d.
Quiescent settlement with chemicals	208	11 5
Continuous flow settlement with chemicals	208	11 5
Quiescent settlement without chemicals	208	11 5
Continuous flow settlement without chemicals	152	8 4
Septic tanks	152	8 4

Loan Charges.

78. Taking the price of land at £100 per acre, and assuming that the loan is raised at $3\frac{1}{2}$ per cent interest per annum and is repayable in equal annual instalments in thirty years, the annual loan charges in respect of the initial cost of tanks and of the land on

which the tanks are constructed and in which the sludge is buried would be as shown in the following table:—

Preliminary Process.	Loan Charges.	
	Per annum.	Per million gallons of sewage (dry weather flow).
	£ s. d.	£ s. d.
Quiescent settlement with chemicals	374 5 9	1 0 6
Continuous flow settlement with chemicals	251 4 11	0 13 9
Quiescent settlement without chemicals	364 7 9	0 19 11
Continuous flow settlement without chemicals	314 12 8	0 17 3
Septic tanks	404 4 11	1 2 2

Total Cost of the Preliminary Processes.

79. Arranged in the order of their total annual cost, including repayment of principal and interest on loans, the five processes are as follows:—

	£ s. d.
Continuous flow settlement without chemicals	564 12 8
Septic tanks (open tanks)	629 4 11
Quiescent settlement without chemicals	724 7 9
Continuous flow settlement with chemicals	1,134 19 11
Quiescent settlement with chemicals	1,258 0 9

The details are:—

Per Annum.

Preliminary Process.	Chemicals.	Labour and Supervision.	Loan Charges.	Total.
	£ s. d.	£	£ s. d.	£ s. d.
Quiescent settlement with chemicals.	523 15 0	360	374 5 9	1,258 0 9
Continuous flow settlement with chemicals.	523 15 0	360	251 4 11	1,134 19 11
Quiescent settlement without chemicals.	—	360	364 7 9	724 7 9
Continuous flow settlement without chemicals.	—	250	314 12 8	564 12 8
Septic tanks	—	225	404 4 11	629 4 11

Per Million Gallons of Sewage (dry weather flow).

Preliminary Process.	Chemicals.	Labour and Supervision.	Loan Charges.	Total
	£ s. d.	s. d.	£ s. d.	£ s. d.
Quiescent settlement with chemicals.	1 8 8	19 9	1 0 6	3 8 11
Continuous flow settlement with chemicals.	1 8 8	19 9	0 13 9	3 2 2
Quiescent settlement without chemicals.	—	19 9	0 19 11	1 19 8
Continuous flow settlement without chemicals.	—	13 8	0 17 3	1 10 11
Septic tanks	—	12 4	1 2 2	1 14 6

In so far, therefore, as the preliminary tank process by itself is concerned, it will be seen that, *on the basis of the above calculations*, settlement either by continuous flow or in open septic tanks is only half as costly as chemical precipitation. It will be noted that quiescent settlement, as compared with continuous flow settlement, does not add greatly to the total annual cost, while it gives distinctly better results.

Filtration of Tank Liquor.

80. In most cases sewage must not only be settled, but must also be filtered, and it is therefore desirable to consider the cost of the preliminary process *in conjunction with* the final or filtration process.

"Strength" of the Liquors Produced.

From the data obtained at Dorking, Leeds, and Huddersfield, where chemical precipitation (continuous flow), settlement without chemicals (continuous flow) and septic tank treatment, have been compared on the same sewage, and from our general experience, we estimate the strengths* of the five tank liquors which would be produced from our hypothetical domestic sewage, and the approximate amount of suspended matter which would be contained in each, as follows :—

Preliminary Process.	* Strength of Sewage.	* Strength of Tank Liquor	Average Amount of Suspended Matter in Tank Liquor.
Quiescent settlement with chemicals	100	50	1 to 4 parts
Continuous flow settlement with chemicals	100	60	3 „ 6 „
Quiescent settlement without chemicals	100	70	5 „ 8 „
Continuous flow settlement without chemicals	100	80	10 „ 15 „
Septic tanks	100	80	10 „ 15 „

Final Purification of the Tank Liquors.

81. On the grounds set out in a later section of this report, we consider that the amount of tank liquor which can be treated on a filter depends upon the strength of the liquor and the amount of suspended matter which it contains, and further, that some filters are more suitable for the filtration of certain kinds of tank liquor than others. For the purpose of our present comparison we have selected percolating filters composed of rather coarse material, say, 1 to 3 inches in diameter. The rate of filtration at which such filters could be used with each of the five preliminary processes, so as to yield satisfactory effluents, is shown in the following table :—

Preliminary Process.	Strength of Tank Liquor.	Amount of Suspended Matter in Tank Liquor (parts per 100,000).	Rate of Filtration per cube yard per day (dry weather flow).	Cubic Content of Filtering Material required to treat 1 million gallons per day (dry weather flow).
			gallons.	cubic yards.
Quiescent settlement with chemicals	50	1 to 4	175	5,714
Continuous flow settlement with chemicals	60	3 „ 6	150	6,666
Quiescent settlement without chemicals	70	5 „ 8	100–125	8,928
Continuous flow settlement without chemicals	80	10 „ 15	75–100	11,494
Septic tanks	80	10 „ 15	75–100	11,494

* The strength is calculated on the basis of the formula suggested by Dr. McGowan, *see* page 16.

The total annual cost of five sets of percolating filters of coarse material, we have calculated to be as follows* :—

Preliminary Process.	Total Cost of Filtration, including loan charges.	
	Per annum.	Per million gallons (dry weather flow).
	£ s. d.	£ s. d.
Quiescent settlement with chemicals	572 19 7	1 11 5
Continuous flow settlement with chemicals	661 11 3	1 16 3
Quiescent settlement without chemicals	766 9 2	2 1 11
Continuous flow settlement without chemicals	960 8 5	2 12 8
Septic tanks	960 8 5	2 12 8

The total cost of the complete treatment in each case (loan charges included) would therefore be as follows :—

Per Annum.

Preliminary Process.	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of complete Treatment.
	£ s. d.	£ s. d.	£ s. d.
Quiescent settlement with chemicals	1,258 0 9	572 19 7	1,831 0 4
Continuous flow settlement with chemicals	1,134 19 11	661 11 3	1,796 11 2
Quiescent settlement without chemicals	724 7 9	766 9 2	1,490 16 11
Continuous flow settlement without chemicals	564 12 8	960 8 5	1,525 1 1
Septic tanks	629 4 11	960 8 5	1,589 13 4

Per Million Gallons (dry weather flow.)

Preliminary Process.	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of complete Treatment.
	£ s. d.	£ s. d.	£ s. d.
Quiescent settlement with chemicals	3 8 11	1 11 5	5 0 4
Continuous flow settlement with chemicals	3 2 2	1 16 3	4 18 5
Quiescent settlement without chemicals	1 19 8	2 1 11	4 1 7
Continuous flow settlement without chemicals	1 10 11	2 12 8	4 3 7
Septic tanks	1 14 6	2 12 8	4 7 2

* *See* page 105.

Arranged in the order of cost the five complete processes are as follows :—

	Total Cost per Annum.			Total Cost per Million Gallons. (dry weather flow).		
	£	s.	d.	£	s.	d.
Quiescent settlement without chemicals - - - - -	1,490	16	11	4	1	7
Continuous flow settlement without chemicals - - -	1,525	1	1	4	3	7
Septic tanks (open) - - - - - - - - -	1,589	13	4	4	7	2
Continuous flow settlement with chemicals - - -	1,796	11	2	4	18	5
Quiescent settlement with chemicals - - - -	1,831	0	4	5	0	4

Conclusions.

82. The above figures have been arrived at by making a number of assumptions, but they are based upon a large mass of evidence and experience.

We have not had an opportunity of making comparative observations, as regards all the processes, at one place.

The figures show that there is little difference as regards annual cost between the processes of quiescent and continuous flow settlement of sewage and septic tank settlement, when these are adopted in conjunction with percolation through filters of coarse material, the maximum difference being only 6 per cent. On the other hand, the two processes of chemical precipitation are from 20 to 25 per cent. more costly than the cheapest of the simple settlement processes. As regards this point, however, it must be remarked that sewage which has undergone chemical precipitation contains less suspended and colloidal matter than sewage which has been passed through a septic tank, or than sewage which has been settled without chemicals, and therefore it can be treated on a filter of finer material, and in that case a smaller number of cubic yards of material than we have allowed for in this comparison would suffice for its purification.

In this connection, it may also be pointed out that, where sewage is freed, as far as possible, from suspended matter, a large extra quantity may, in times of storms, be passed through coarse percolating filters, without injury to the filters.*

In the absence of special circumstances favouring a particular plan, it would appear that there is very little difference in annual cost between the various methods of tank treatment followed by filtration through percolating filters, assuming that the kind of filter adopted in each case is that which is best adapted to the particular tank treatment provided.

Some Observations on the Choice of Tank Treatment.

83. The form of preliminary treatment which should be adopted at a given place should depend *mainly* upon the means at hand for the disposal of sludge, and upon the class of filter to be used in the subsequent filtration of the tank liquor. If fine filters are to be used for the oxidation of the tank liquor, the tank treatment should generally be such as will eliminate a large proportion of the suspended and colloidal matter.

We shall make some further observations on this aspect of the question in the section dealing with filters. With a tank liquor of given strength, and containing a given quantity of suspended and colloidal matter, it is of little consequence, as regards the subsequent filtration, by what method of preliminary treatment this liquor has been obtained.†

* *See* Leeds Report 1905, pp. 114, 115.

† From the result of the experiments at present in progress at Dorking, the above statement may have to be somewhat modified. The neutralisation of the sulphuretted hydrogen of the septic liquor and the slightly increased alkalinity given by the lime appear to allow of a very considerable increase in the volume which may be filtered per cube yard, greater than would follow from the mere reduction in suspended solids effected by this precipitation.

The nature of the sewage to be treated should, however, be considered in selecting the tank treatment to be adopted.

Domestic sewages may be divided into three classes, viz. :—

(1) Domestic sewages which are very strong ;

(2) Domestic sewages of about average strength ; and

(3) Weak domestic sewages.

Domestic Sewages which are very Strong.

84. Very strong sewages, derived from towns where the water-closet system is in vogue, contain more suspended and colloidal matter than weak sewages. Our analyses, so far as they go, have shown that the actual proportion of colloidal to suspended matter in sewage is not great ; but since the amount of colloidal matter is frequently somewhat larger in a septic tank liquor than in its corresponding sewage, the proportion of colloidal to suspended matter in a strong septic tank liquor may be considerable. Such a liquor would exercise a greater clogging effect upon a filter of fine or medium-sized material than its figure for " suspended solids " would lead one to expect. Moreover, the septic liquor and sludge produced from such a sewage would almost certainly give rise to considerable smell, and if the sewage contained much brewery or tannery waste the smell would be still more pronounced.

Where sewage has to be pumped its character may be abnormal. It may remain for a considerable time in the main sewer or sewers, and become " septic " in character before it reaches the outfall. Moreover, in such cases, surface water is often rigorously excluded so as to diminish the cost of pumping, and the strength of the sewage is thus increased.

In the majority of cases we think it would probably be better to adopt chemical precipitation rather than septic tanks as the preliminary process for very strong water-closet domestic sewages, and especially would this be the case if the sewage contained an appreciable quantity of brewery or tannery waste.* Precipitation with chemicals has the effect of throwing down, as sludge, a considerable proportion of the colloidal matter present, and some precipitants have the power of retarding for a short time the putrefaction of the sludge, so that precipitation sludge, if removed from the tanks at short intervals of time, can usually be disposed of with less danger of nuisance than septic tank sludge. It may also be remarked that the addition of lime to a putrid domestic sewage is followed by a great diminution of the smell.

Moreover, chemically precipitated sludge is, volume for volume, usually much less costly to press than septic tank sludge, especially if it is derived from a strong domestic sewage of the kind indicated above ; indeed the quantity of lime which has to be added to some septic tank sludges makes the cost of pressing almost prohibitive.

Simple sedimentation of a sewage of this class would also be less advantageous than chemical precipitation. Little colloidal matter would be removed from the sewage, and there would be more danger of nuisance from smell during the sludging of the tanks and the sludge disposal operations.

85. As regards very strong domestic sewages consisting for the most part of slop-water there is, apart from the question of cost, little to choose between the various methods of settlement. The bulk of the suspended matter in such a sewage settles fairly rapidly, leaving a soapy liquid containing a considerable quantity of greasy suspended matter. Such sewages are, however, usually to be found at small places where labour for frequent sludging would not be available, and in these circumstances septic tanks would usually be more economical than sedimentation or chemical precipitation tanks, and they would produce a tank liquor which would be suitable for filtration through coarse filters.

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* The success which has attended the treatment of the Dorking septic tank liquor with a small quantity of lime makes it appear possible that in some cases the combination of the two processes—*i.e.*, septic tank treatment followed by lime precipitation—would be preferable to precipitation alone (*c.f.* paragraph 56 and note on p. 43).

We have had opportunities for observing the treatment of sewages of this kind by various methods of settlement, including septic tanks (Hemsworth), settling tanks used on the continuous flow plan (Clifton, Lancashire), and chemical precipitation followed by quiescent settlement (Withnell). The two examples of chemical precipitation followed by continuous flow settlement which we have had under observation—Calverley and Normanton (Yorkshire)—did not give very good results as regards settlement, the suspended matter in the tank liquor being above 12 parts per 100,000 in both cases. The reasons for this were that the sewage varied greatly in strength throughout the day, and the proper addition of the precipitant was a matter of much difficulty ; and, as is common at some places, the tanks were allowed to run too long without cleaning.

Domestic Sewages of about Average Strength.

86. For domestic sewages of about average strength, whether of the slop-water or water-closet type, the choice of the preliminary process should depend upon local circumstances and upon the kind of filters to be adopted. With such sewages equally good final results may be obtained either from septic, sedimentation, or chemical precipitation tanks, followed by artificial filters, though the size of the material to be used in the filter should depend, to some extent, on which tank treatment was adopted. The least amount of sludge is produced by the septic tank and the greatest amount by the chemical precipitation tank, but a larger area of filter is required for the treatment of the septic tank liquor than for the treatment of the precipitation tank liquor. Approximately the same filter area is required for the filtration of sewage from sedimentation tanks used with a continuous flow as for septic tank liquor. If quiescent sedimentation is adopted, a smaller area of filter will suffice. Excepting at very small places, where the labour costs for the constant sludging of the tanks would be disproportionately high, or in cases where pumping would be required, quiescent sedimentation gives considerably better results as regards suspended matter than continuous flow sedimentation, at practically the same cost.

Weak Domestic Sewage.

87. The last 4 or 5 parts of suspended matter are extremely difficult to throw down as sludge, and in the case of weak sewages the difference between the various tank treatments, as regards suspended matter in the resulting liquors, is not nearly so great as it is in the case of strong sewage.

For this reason, the advantage as regards amount of sludge produced and saving in cost of chemicals which the preliminary processes of septic tank treatment and continuous flow sedimentation have over chemical precipitation, is of greater importance with weak than with strong sewages. The septic tank process would, we think, generally be most economical for a weak sewage, if land were available for the burial of the sludge. The sludge produced would not have a very offensive smell, and might indeed in some cases be comparatively free from smell. If, however, no land were available for the burial of the sludge, the extra cost of pressing septic tank sludge would materially diminish the advantage of septic tank treatment.

Summary for Domestic Sewage.

88. Speaking generally, we should say that chemical precipitation is more suitable for strong sewages or sewages likely to give rise to nuisance, while septic tank treatment or sedimentation would usually hold the advantage in the case of weak sewage. For sewage of about average strength there is probably little difference between the three processes, and the selection of the process would depend chiefly upon the facilities for sludge disposal, the position of the works as regards houses, and the kind of filters to be adopted.

It must be remembered, however, that there are other considerations which may affect the question. A particular sewage, for example, may be liable to great variations in strength and character, and the equalising effect which the septic tank has on such a sewage is a point of considerable importance.

Moreover, it is by no means to be thought that finality has been reached in the preliminary treatment of sewage. New combinations of tanks or of processes may lead to much improvement; a cheap deodorant for sludge may be found, etc. In this connection, we may refer to the results of our experiments at Dorking upon the treatment of sewage by septic tanks, followed by precipitation with lime, which are mentioned on p. 29.

Sewage from large Cities.

89. The presence of trade waste in large or preponderating quantity has an important bearing upon the preliminary treatment of the sewage from a large city. Where the sewage contained much brewery waste, lime would probably have to be added for the purpose of neutralisation, as at Burton-on-Trent; where it was strongly alkaline, or very greasy, acid might have to be used as the precipitant, as at Bradford; where it contained much tarry matter or matter which had an inhibitory effect upon the activity of purifying organisms, septic tanks might be preferable, by reason of the longer stay which they give to the sewage. Manchester may be cited as an example of this last case. For these reasons it is impossible to make any but the broadest generalisations with regard to the preliminary treatment of the sewage from large cities, whether it be weak or strong.

Where very large areas of filters have to be put down, it is of considerable importance to protect them against clogging, and we think that it will usually be found best in the case of a large city to adopt effective means for the removal of most of the suspended matter before filtration. In the majority of cases this would involve the adoption of chemical precipitation, though not necessarily in all, for Mr. Watson, of Birmingham, has shown that a well clarified tank liquor can be obtained by interposing Dortmund tanks between the septic tanks and the filters. The Birmingham septic liquor contains on the average about 20 parts of suspended matter before entering the Dortmund tanks, but only about 6 parts when it leaves them. This liquor from the Dortmund tanks has now been treated for some years on percolating filters without serious clogging. It must be pointed out as regards Birmingham, however, that at that place there is a very large area of land available for the disposal of sludge. If it were not for this, sludge pressing might have been necessary, and having regard to the difficulty of pressing septic tank sludge, it might have been desirable to adopt chemical precipitation.

PART II.—PURIFICATION OF SEWAGE BY ARTIFICIAL FILTERS.

INTRODUCTORY REMARKS.

90. Sewage filters may be divided into two broad classes:—contact beds and percolating filters.

Contact beds are tanks filled with some filtering medium. In this type of filter, the sewage is held up before it is discharged. The bed, after it is emptied, is allowed to remain empty for some time before receiving the next filling. The length of time during which the sewage is allowed to stand in the bed is spoken of as the period of contact.

In percolating filters the sewage is not held up, but is allowed to percolate through the filter.

There can be no doubt that the organic matter in solution in sewage can be oxidised by either type of filter, provided the filter is properly constructed and properly worked, but the question of the relative merits of the two types is one of some difficulty, as very few strictly comparative experiments on a large scale have been made.

SOME OBSERVATIONS AS TO THE EXTENT TO WHICH THE SUSPENDED SOLIDS SHOULD BE REMOVED FROM SEWAGE BEFORE IT IS FILTERED.

91. No rule can be laid down as to the extent to which the suspended solids should be removed from sewage before it is filtered, but, speaking generally, if it is proposed to use filters of fine material, we think it will be found most economical to adopt some form of tank treatment which will yield a tank liquor fairly free from suspended solids; whereas, if coarse filtering material is to be used, this is not so essential.

If much suspended matter is put on fine filters, they are likely to choke very rapidly unless the rate of filtration is very slow.

Under the heading "Some observations on the choice of a method of sewage treatment," page 202, a number of points are mentioned which should be taken into account in determining what method of treatment should be adopted in any particular place, and in this section we only propose to give the results of our general experience as to the amounts of suspended matter, which, having due regard to the life of the filter and to the quality of effluent, may be allowed with certain kinds of filters, worked at certain rates.

The figures relate to domestic sewage, or sewage containing only small amounts of trade refuse, of average strength.

The rates of filtration which we give could generally be doubled in wet weather. Thus, assuming it was desired to provide enough filtering material to filter in storm times up to three times the dry weather flow of sewage, the amount of material required would be 50 per cent. more than the amount which would be required for the dry weather flow, calculated on our figures.

I.—Contact Beds.

Coarse Material (3 ins. diameter and upwards).

92. Grit-settled sewage containing 20 to 30 parts of suspended matter could be treated at the rate of 1 to 1½ fillings per day (about 30 to 40 gallons per cube yard* per day for double contact) upon material of this size in contact beds; if the sewage contained 30 to 50 parts of suspended matter per 100,000, the rate of treatment should not exceed 1 filling per day (about 30 gallons per cube yard per day for double contact). In both cases provision would have to be made for thoroughly washing the material in the beds about once every 18 months or 2 years. Secondary beds of medium-sized material, used subsequently, would probably have to be washed every 4 or 6 years.

Medium-sized Material (½ in. to 1 in. diameter).

93. Tank liquors containing 10 to 15 parts of suspended matter per 100,000 could be treated upon material of this size at the rate of about 2 fillings per day (50 gallons per cube yard* of filtering material per day for double contact, or 100 gallons per cube yard for single contact), but the material would have to be thoroughly washed or renewed every 3 to 5 years. If the tank liquor contained from 4 to 7 parts of suspended matter per 100,000, the rate of treatment might be 3 (about 80 gallons per cube yard* per day for double contact, or 160 gallons per cube yard for single contact) or, at times, 4 fillings per day, and the beds would probably have to be washed every 4 or 5 years. In both these cases the material in the secondary beds would probably not require to be washed for 7 or 8 years.

* See footnote on next page.

If the liquor contained from 1 to 4 parts of suspended matter per 100,000 it could probably be treated at a rate of 4 to 6 † fillings per 24 hours (about 100 to 160 gallons per cube yard * per day, for double contact), and the material might not need washing for 6 to 8 years, or possibly even longer. Secondary beds, in this case, would probably last for 12 or 15 years.

Fine Material ($\frac{1}{4}$ *in. diameter*).

94. It would be inadvisable, we think, to attempt to treat tank liquors containing more than 4 or 5 parts of suspended matter per 100,000, on material of this size. A good tank liquor, containing from 1 to 4 parts of suspended matter could, probably, be well filtered at the rate of from 4 to 6 * fillings per day (about 100 to 160 gallons per cube yard † per day for double contact or 200 to 320 gallons per cube yard for single contact), and the material would, probably, not have to be washed for 6 or 8 years. The upper part of the material in secondary beds would, probably, have to be washed every 12 or 15 years.

II.—Percolating Filters.

Coarse Material (3 *in. diameter and upwards*).

95. Grit-settled and screened sewage could be treated on a percolating filter composed of material of this size even if it contained as much as 30 parts of suspended matter per 100,000, provided such suspended matter was not largely made up of fibrous material, hops, etc. If the sewage was of average strength, it could, probably, be filtered at a rate of about 50 gallons per cube yard per day. The upper part of the material would, we think, have to be removed and replaced about every 2 years, and the lower part flushed through with water or clarified sewage.

Tank liquors containing, say, 10 to 20 parts of suspended matter per 100,000, might be treated upon this material for long periods of time (say, 10 to 15 years) with occasional renewal of the top foot of material. If the tank liquor was of about average strength, it could be filtered at a rate of about 100 gallons per cube yard per day.

A tank liquor of about average strength, containing from 4 to 7 parts of suspended matter per 100,000, could similarly be treated on coarse material, but in this case the rate of filtration might be about 100 to 150 gallons per cube yard per day.

A tank liquor, containing from 1 to 4 parts of suspended matter per 100,000, could be filtered for even longer periods of time on coarse material, and, if it were of about average strength, at a rate of 150 or possibly 200 gallons per cube yard per day.

In all these cases the filtration might occasionally be affected by fungoid growths on the surfaces of the filters. Provision would generally have to be made in the first three cases, and possibly in the last also, for the settlement or the straining, through fine material, of the filter effluent, in order to reduce the suspended matter contained in it.

Medium-sized Material ($\frac{1}{2}$ *in. to* 1 *in. diameter*).

96. Grit-settled and thoroughly screened sewage could generally be treated upon material of this size, even though it contained as much as 30 parts of suspended matter per 100,000. The rate of filtration, however, should not exceed 25 gallons per cube yard per day, and even in that case the upper part of the material would probably require to be washed every 2 or 3 years. The plan would, we think, not be economical, except at very small places.

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* There are good grounds for putting the average water capacity of a primary contact bed during its working life at about 33 per cent. of its original empty tank capacity. These estimates are consequently based upon that assumption. We estimate that the average capacity of a secondary bed during the lifetime of its complementary primary bed, is about 40 per cent. of its original empty tank capacity. If this is taken into account, *i.e.*, if the secondary beds are made proportionately smaller than the primary beds, the rates of filtration per cube yard per day will be rather greater in each of the cases given above.

† With large beds such a high rate of working would, probably, be only practicable for short periods of time.

Tank liquors containing from 10 to 15 parts of suspended matter per 100,000 could generally be treated on this material at a rate of about 50 gallons per cube yard per day, if the upper part of the material were washed or renewed once in 3 or 4 years, and provided also that the bed were well rested immediately any signs of ponding occurred.

A tank liquor containing from 4 to 7 parts of suspended matter per 100,000 could generally be filtered at a rate of 75 to 100 gallons per cube yard per day. The upper part of the material would probably require washing or renewal once in 3 to 5 years.

A very good tank liquor containing from 1 to 4 parts of suspended matter could generally be filtered at a rate of 150 to 200 gallons per cube yard per day, provided the filter were carefully rested when necessary, and also that the liquor was not of a kind liable to give rise to fungoid growths. The material in this case would probably last without washing for 5 or 6 years, or possibly even longer, though it might be advisable to wash or renew the uppermost few inches every 1 or 2 years.

In the first three mentioned cases, and possibly in the last also, provision would usually have to be made for the reduction of the suspended matter in the filter effluent.

Fine Material ($\frac{1}{4}$ *in. diameter*).

97. It would be inadvisable, we think, to attempt to filter tank liquors containing more than 6 or 7 parts of suspended matter per 100,000 on material as fine as this. Crude sewage, for instance, would clog the surface of such material in a very short time, unless the rate of filtration were exceedingly slow, and even then the surface of the material would have to be constantly scraped and cleaned.

Tank liquors containing from 4 to 7 parts of suspended matter per 100,000 could generally be filtered at a rate of 75 to 100 gallons per cube yard per day. The upper part of the material would require washing or renewal about once in 4 or 5 years.

A tank liquor containing from 1 to 4 parts of suspended matter per 100,000 could probably be filtered at a rate of 150 to 200 gallons per cube yard per day, and the material in the upper part of the filter would probably require washing once in 4 or 5 years. The higher rate could only be maintained, if the filters were shallow.

Very fine Material ($\frac{1}{8}$ *in. diameter and smaller*).

98. Where material, such as sand, is used for a filter, or where the filter is protected with a surface layer of sand, only very well clarified tank liquors can be treated, unless the rate of filtration is very slow and the surfaces of the beds are scraped or washed at short intervals. Such filters must necessarily be used intermittently.

For tank liquors containing from 4 to 7 parts of suspended matter per 100,000, the rate of filtration should probably not exceed 50 gallons per cube yard per day, and the surfaces of the filters would have to be scraped after every one or two applications of the liquor. If the fine material alone were relied upon for the distribution of the liquid, the rate of filtration might possibly have to be slower. If very fine-grained filters were arranged in the shallow form and were washed by upward flow every one or two weeks, it would be possible to treat a very good tank liquor from a sewage of about average strength, containing, say, 1 to 4 parts of suspended matter per 100,000, at rates of from 200 to 300 gallons per cube yard per 24 hours. The liquor would have to be delivered intermittently, and the distribution must of course be efficient. At Chorley, where such a tank liquor is delivered on to filters of this kind, the rate of filtration is upwards of 350 gallons per cube yard per day. Here, the tank liquor is delivered in large flushes which cover the whole surface of each bed to a depth of 2 or 3 inches, and the surface of the beds is frequently washed.

CONTACT BEDS.

99. Our knowledge of the action of a contact bed is very incomplete, and little is known as to the manner in which the organic substances of sewage are broken down during the first stages of fermentation into carbon dioxide, ammonia, etc. The purifying agents seem to be not only bacteria, but also worms, larvæ, insects, etc., and we can offer no opinion as to the respective amount of work done by each set of agents. It probably differs to some extent according to the nature of the sewage. It has been observed that at some places large numbers of worms are present, while at others there are comparatively few. Little is known of the kind of bacteria essential for purification, or as to their mode of action, and we are not able to state whether they act chiefly during the period of contact or during the period of rest, or aeration, after the filter is emptied. There are, however, grounds for thinking that the resting period is the more important phase of the cycle.

The generally accepted theory as regards nitrogenous matter seems to be that the ammonia is extracted from the liquid during the period of contact, and oxidized during the period of rest, and that the resulting nitrate and nitrite are diffused through the liquid of a subsequent filling. All the ammoniacal nitrogen, however, does not appear in the effluent in the oxidized state, for there is always loss of nitrogen, as nitrogen gas, during the process.

The withdrawal of suspended and colloidal matter from the sewage during its passage through the bed appears not to be a simple mechanical effect of the material, for a matured contact bed, not clogged, will withdraw more suspended matter from the sewage than another bed similar in all other respects, but not matured. As regards the action which takes place in a contact bed, we may also refer to the evidence of Mr. Dibdin, Dr. Rideal, Mr. Harrison, Mr. Valentine and Dr. Fowler.

Dibdin, 2176, 3902–5.
Rideal, 4133, 4207–8.
Harrison, 22021.
Valentine, 22475
Fowler, 22815.

Construction of Contact Beds.

100. In some cases contact beds have been made by simple excavation, but our experience and the evidence which we have received show that in the majority of cases it is desirable that the beds should be constructed of building materials.

When contact beds are constructed by simple excavation in clay soil, there is risk of the clay sooner or later, according to the character of the stratum, working up into the filtering material. Moreover, the lines of underdrains are apt to become distorted, as the result of unequal settlement.

Wilkinson, 24282.
Wike, 23588.

At Heywood an experimental bed was constructed, without concrete, in clay soil, and it was found that the clay worked up into the bed and formed an impervious mass round the drain pipes.

Again, there is danger of leakage unless the soil is of a very dense nature and the embankments are of considerable width. This leakage may occur as a result of unequal settlement, or through rats or moles burrowing into the embankment, or through the cracking of the clay during periods of rest or frost. The result of leakage may be detrimental to the working of the bed. Two instances which have come under our own observation may be mentioned.

At Halton it was found necessary to fill two of the primary contact beds simultaneously, as the liquid percolated from one bed to the other through the intermediate embankment.

At Oswestry, where double contact beds were constructed in fairly stiff clay soil, some of the retaining banks became sodden with liquid after three or four years' work and sank considerably in consequence.

Even in the most impervious kind of soil the outlet chambers of contact beds must be constructed of building materials, and, unless this work is most carefully carried out, there is danger of leakage at the juncture of the chamber and the embankment. It may also be remarked that the embankments required, where no building materials are used, take up more space than properly built walls.

On the other hand, where the site for the works consists of a dense clay, experience shows that the construction of contact beds by simple excavation may be satisfactory.

As examples, we may refer to the beds at Burnley and Oldham.

At Burnley twenty-four acres of double contact beds have been constructed by simple excavation in loam and heavy clay soil. The oldest of the Burnley beds was brought into use about ten years ago.

At Oldham, where the soil is chiefly clay, with pockets of sand in places, five acres of single contact beds have been constructed by simple excavation, the sides being puddled where necessary and boarded up with 3-inch planking.

In both these cases the construction has been fairly satisfactory.

101. The construction of the bottom of a contact bed should be such as to allow of the treated liquid being drawn off quickly, but quietly, in order to give the material the longest possible rest and aeration.

The liquid which, at the commencement of the filling, finds its way into the drains of a contact bed is not purified to the same degree as the bulk of the liquid throughout the filtering material, and, for this reason, the drains of a contact bed should not be larger than is necessary to allow of the thorough draining of the bed.*

It has been suggested that this difficulty of unequal purification might, to some extent, be overcome by constructing the drains so that they would remain full of filter effluent after the bed had been run off. We are not aware that this course has been actually tried, but if it were adopted, great care would have to be taken to construct the drains below the level of the material, and to place the outlet valve in such a position as to preclude the possibility of effluent standing amongst the lower layers of the material during the resting period. Whether the aeration of the bed, during the "rest," would be affected we are unable to say. In any case it would be inadvisable to attempt this plan of draining where the bottom was not constructed of concrete or some such material.

In order that the withdrawal of the liquid may be gentle, as well as rapid, it is desirable to provide several drains, especially in a large bed.

102. Two points of detail may be mentioned here which are of some importance :—

The outlet valve of a contact bed should be fixed in such a position that a proper sample of the filter effluent can be collected from it. In a number of cases we have found it very difficult to draw proper samples of effluent from contact beds, owing to the outlet valves being placed low down in the channel along which effluents from other beds were flowing, and in these cases it has not been easy to ascertain the efficiency of the individual beds.

The feed channels to the secondary beds should be constructed so as to provide reasonable facilities for measuring the capacity of the beds. These beds are frequently so constructed that accurate measurements of capacity cannot be made.

Depth of Contact Beds.

103. The evidence shows that, within ordinary limits, the depth of a contact bed makes, practically, no difference to its efficiency per cube yard.

At Leeds, experiments were made with three contact beds of different depths, filled with similar material, and treating the same tank liquor. These beds were, respectively, 5 feet deep, 4 feet deep, and 3 feet 6 inches deep.

The bed 5 feet in depth received septic tank liquor at the rate of two fillings per day, with one week's rest in every four. During the period from July, 1901, to March, 1905, the effluent showed, according to Mr. Harrison's analyses, an average reduction of 78·6 per cent. in oxygen absorbed from permanganate in four hours.

* *Note.*—The actual size of the drains would depend to some extent upon the size of the material.

The bed 4 feet deep received septic tank liquor at the rate of one filling per 24 hours, from August 17th, 1901, to January 11th, 1905. The effluent showed an average reduction in oxygen absorbed from permanganate in four hours of 80·3 per cent.

The bed 3 feet 6 inches deep received septic tank liquor for fourteen months, at a rate of three fillings per day, and gave an average reduction in oxygen absorbed from permanganate in four hours of 74 per cent.

Taking into account the differences in working, there was no great difference in the results obtained in this experiment, and so far as we could judge from a careful comparison of the results at the time the experiments were made, none which could be ascribed to the depth of the filters.

The experience of Dr. Clowes in connection with some experiments which he carried out at the London sewage works was in agreement with that of the Leeds experiments.

For further details on this question reference may be made to the evidence of Mr. Harrison, 22005; Mr. Valentine, 22450; Dr. Fowler, 22792; Mr. Wyke, 23599; Mr. Wilkinson, 24283; Mr. Campbell, 21652 and 21883; and Dr. J. B. Wilkinson, 22643.

104. From our own experience of contact beds, we think that it would be generally inadvisable to construct them of a greater depth than 6 feet or of a less depth than 2 feet 6 inches.

In order that a contact bed may drain properly, it is necessary to have a few inches of large material on the floor of the bed, and this material, with the drains themselves, would occupy about 6 inches of depth. The sewage which remains among this coarse material, or in the drain spaces, during the time when the bed is full, is not so well purified as the liquor which is standing amongst the finer material in the upper part of the bed, and it is found that the first flush from a contact bed, which comes from the lowest part of the bed, is usually considerably worse than the main bulk of the effluent. As a general rule, we doubt whether it would be wise to allow this less efficient portion of the bed to form more than one-fifth of the whole depth, and for this reason we suggest that the minimum depth should usually be not less than 2 feet 6 inches.

As regards the maximum depth of contact beds we may observe :—

(*a*) That an increase in depth puts a greater weight upon the filtering material in the lower part of the bed, and may cause disintegration.

(*b*) That the difficulty of digging and handling the material, when washing is necessary, is greater with deep than with shallow beds, and that the operation would require a greater amount of labour and would result in more breaking down of the material during the process.

105. Our experience of contact beds ranges from the deepest of the Leeds beds, 6 feet deep, to the shallow contact beds at Oldham, 1 foot 6 inches deep, the depths of the contact beds at the various places which we have had under observation being :—

Leeds	From 6 feet to 3 feet.
Exeter (St. Leonards)	5 feet.
Hendon	5 feet (about).
Slaithwaite	5 feet.
Withnell	5 feet and 3 feet 6 inches.
Oswestry	4 feet 6 inches.
Exeter (Main works)	4 feet 6 inches.
Maidstone	4 feet 4 inches and 3 feet 3 inches.
Halton	4 feet 3 inches and 3 feet 3 inches.
Hartley Wintney	4 feet.
Andover	4 feet.

Hampton	4 feet.
Newton-le-Willows	3 feet 6 inches.
Calverley	3 feet.
Guildford	2 feet 6 inches.
Oldham	1 foot 6 inches.

Filling and Emptying of Contact Beds.

106. The evidence shows that two hours' contact and four hours' rest have generally been found to give the best results in practical working, where the beds are filled three times a day, but no rule can be laid down which is of universal application.

As regards this question Dr. Fowler stated in reference to his Manchester experience that the periods depend almost "entirely on the age of the bed and the dilution of the
Fowler, 22798 "sewage. In the initial stages of working, long contacts (*e.g.*, twenty-four hours) have been "found advantageous, their effect being to facilitate the formation of a slimy layer of col- "loidal matter on the medium, in which the real biological action begins. As this layer "increases, the 'absorptive' effect increases also, and less time of contact is required. More- "over, a greater quantity of water is held up in a bed, and the quantity of 'draining' in- "creases, till with a bed in long use a very short contact, say, a quarter of an hour, is all "that is required. With increase in dilution of the tank effluent, due, *e.g.*, to storm water, "the period of contact may be reduced to a minimum. In general, after the bed is once "'mature,' the period of rest is more important than the period of contact, and the total "time occupied in twenty-four hours in filling, standing full, and emptying should not "exceed the total of the period of rest. Thus, with frequent fillings, the time of contact "should be shortened. If the bed takes long to fill, the extra time in filling should be taken "from the time of contact. The above also applies to secondary beds, it being understood "that, as they deal with an effluent containing less impurity, they can be worked more "rapidly than primary beds."

At Calverley the period occupied by filling and standing full varied from six to twenty-four hours, the beds being filled, on an average, less than once a day. A good percentage purification on a strong precipitation liquor was obtained by single contact, but the liquor was too strong to allow of single contact producing a satisfactory effluent. The beds retained their capacity well. A long contact apparently helps to break down the suspended solids and to allow of their passing out of the beds in very considerable quantity.

107. Unless the circumstances are exceptional, we think that, in designing a contact bed scheme, a contact of two hours' duration should be provided for, leaving subsequent experience to show whether this could not be shortened to some extent. The period of contact should be fairly regular, as sudden variations may, we think, have a disturbing effect upon the agents of purification. We have noticed, for instance, in beds generally giving two hours' contact, that if the sewage is occasionally held up for a much longer time, say, five or six hours, great numbers of worms are driven to the surface.

It is also desirable that the fillings should be as far apart from one another as practicable, (*e.g.*, to give three fillings in three cycles of eight hours each, rather than three fillings in twelve hours followed by a twelve hours' rest), so that the maximum period for drainage and aeration between the fillings may be obtained.

108. The operations of filling and emptying should be carried out as rapidly as possible, but care must be taken to avoid disturbance of the filtering material, as this may cause disintegration.

Harding, 7051. *et seq.* Ross and Pickles, 2077. Harrison, Fowler, 22799. Wike, 23565. Wilkinson, 24920.

Further, the evidence shows that the liquid should be passed on to the filter fairly evenly over its whole surface, so that the suspended solids may, as far as practicable, be spread over the whole surface and prevented from entering the bed.

109. With a view to avoiding nuisance, the feed channels have, in some few cases, been placed slightly below the surface of the material, and no doubt the smell from the beds has been thereby lessened. But beds fed in this way would, we think, require more frequent attention to prevent clogging.

In one or two cases upward filling of contact beds has been suggested for a similar reason. This method of filling would, no doubt, lessen the risk of nuisance, but the difficulty of maintaining the capacity of beds worked in this way would be serious.

Automatic Gear.

110. We have had many opportunities of studying the use of automatic apparatus for filling and emptying contact beds, and we have received evidence from several witnesses who have had considerable experience of these devices.

Our own observations and the experience of others show that it is not possible to rely entirely on automatic apparatus for sewage works, although within certain limits it may be advantageously used with considerable saving of labour.

In the case of large sewage disposal works, where men are always available, we consider that it would usually be inexpedient to provide automatic plant. It is liable to get out of order, it does not adapt itself to variations in volume and strength of sewage, state of beds, etc., and generally it is preferable to work the beds by manual labour, where such labour is at hand.

At Manchester, automatic gear was given a careful trial, with a view to its ultimate adoption, if successful. It had, however, to be abandoned, and in reference to this Dr. G. J. Fowler stated :—

> "I have had considerable experience of these devices, both on the experi- Fowler, 22800.
> "mental and working scale at the Davyhulme works, and also at the Withington
> "works. My experience leads me to think that in large works, where skilled
> "supervision must be provided in any case, there is no advantage in their use.
>
> "In small works I think some simple mechanism is useful, chiefly on
> "economic grounds, but it should not be left without some attention, if pos-
> "sible, at least once a day. In small works, with the filtering area divided into
> "few units, great fluctuations may occur in the cycle unless some arrangement
> "of dosing tank is provided, or storage in the main tank (septic or other). These
> "fluctuations may be harmful by causing the time of filling to be too prolonged,
> "with consequent curtailment of the resting period. The chief difficulty, how-
> "ever, is the constant variation in the water-holding capacity of the beds and
> "in the permeability of the surface, causing pondage and irregular working."

We may also refer to the evidence of Messrs. Raymond Ross and Pickles in regard to to the Burnley works. They stated :— Ross and Pickles, 20778.

> "We have not used any automatic apparatus for filling or discharging.
> "The reasons which have led to the exclusion of automatic apparatus are as
> "follows :—
>
> (1) "They are very liable to get out of order, and consequently it is necessary
> "to have a man always on the watch to see that they are working properly.
> "As the attendance of one man is all that is required at our works
> "to control the valves, no saving of wages would be effected, but there
> "would be considerable increase in capital outlay, as all the appliances
> "are expensive to instal, and, we think, costly to maintain.
>
> (2) "Automatic apparatus takes no notice of the condition of the bed, which,
> "in our opinion, is a matter of considerable importance.
>
> (3) "Where the flow of sewage varies, it is desirable to be able to bring the
> "larger beds into use during the time of the greatest flow, so that their
> "period of filling may approximately equal that of the smaller beds. This,
> "we consider, is best accomplished by hand control."

Similar evidence was given by other witnesses.

In the case of small sewage works, however, where labour would not always be available, automatic gear for filling and emptying the beds would often effect considerable saving. Where automatic gear is provided, proper arrangements should be made for the treatment of storm water or sewage overflow arising from a breakdown in the gear. In no case can personal attention be dispensed with entirely.

Loss of Capacity of Contact Beds.

111. The loss of capacity of contact beds is undoubtedly a serious drawback to their efficiency. The evidence shows that the loss chiefly depends upon the following factors:—

(1) Disintegration of the filtering material.
(2) Consolidation of the filtering material.
(3) Deposition of colloidal matter.
(4) Growth of organisms.
(5) The volume of liquid passed on to the bed.
(6) Insufficient rest.
(7) Inefficient drainage.
(8) The amount of suspended matter in the liquid passed on to the bed.

(1) *Disintegration of the Filtering Material.*

112. In the experiments made by Colonel T. W. Harding and Mr. W. H. Harrison at Leeds, the material in nearly all the contact beds was found to have disintegrated considerably.

One of the first of these experiments related to the treatment of crude sewage on contact beds, filled with particles of coke over 3 inches in diameter. This experiment lasted from October 2nd, 1897, to September 8th, 1898, and the coke, in both the primary and secondary beds, suffered considerable disintegration. When the experiment was completed, the material in the primary beds was taken out and only that coke replaced which could not pass through a $1\frac{1}{2}$ inch mesh. Colonel Harding and Mr. Harrison computed the volume of coke rejected in this way at 45·25 per cent. They concluded that if a material could have been used which was not liable to degradation, probably one-third of the loss of capacity would have been avoided.

In the clinker beds, crude sewage, chemically precipitated sewage, and septic tank liquor were treated, and in the case of these beds, also, considerable disintegration took place.

At Hartley Wintney, where soft furnace clinker was used, we observed that the material had disintegrated considerably after five years' work, and we came to the conclusion that this was one of the chief causes of loss of capacity of contact beds at that place.

At Burnley, where a large area of contact beds has been in use for some years, it has been found that the disintegration of the material has caused a considerable loss of capacity. The experience of Burnley, however, has shown that much of the material which has broken down in primary beds may be used with advantage in secondary beds, and that beds which are filled with old material, after it has been washed and re-screened, do not lose capacity so rapidly as beds constructed of new material.

The experience of Manchester in regard to the disintegration of material is also of value. The following data have been given to us as representing a typical case:—

Contact bed No. 10 was first brought into use on May 2nd, 1902, the bulk of the material of which it was composed consisting of dry screened boiler clinker and cinders rejected by a $\frac{3}{16}$ inch mesh. There was also large clinker over the line of drains. After having received 2,578 fillings the bed was stopped, and the whole of the material was washed against a $\frac{1}{4}$ inch mesh sieve. As a result of this screening, 24·1 per cent. of the material was found to be too small to go back into the bed. About two-thirds of this was $\frac{1}{8}$ to $\frac{1}{4}$ inch in size, and was available for the surface of the secondary beds. The actual loss of material, after allowing for the re-use of the material on secondary beds, was estimated by Dr. Fowler at about 8 per cent. to 10 per cent. of the original material.

At Newton-le-Willows, the material (furnace clinker) in all the contact beds at the central works was taken out and re-screened after six years' use. In June, 1900, when the beds were first brought into operation, the material consisted of particles from $\frac{1}{2}$ inch to 2 inches diameter. As a result of the re-screening, which took place between March and September, 1906, Mr. Arthur Bowes, the Surveyor to the Newton-in-Makerfield Urban District Council, estimated that about 25 per cent. was too small to be used again.

At Andover, a bed which was under observation by Mr. R. W. Knapp, was first brought into use on August 13th, 1901, the bulk of the material (hard furnace clinker) being, at that time, from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch diameter. In August, 1905, the bed was stopped and the material taken out and riddled, with the result that only 75 per cent. was found to be still $\frac{1}{8}$ inch to $\frac{1}{2}$ inch in diameter. The remainder had become too small to go back into the bed.

At Oswestry, where ordinary house cinders were used in the primary beds, considerable disintegration took place after about six years' working.

These, and other experiments, leave no room for doubt that a considerable proportion of the loss of capacity of contact beds is due to the disintegration of the material of which the bed is formed.

(2) *Consolidation of the Filtering Material.*

113. Consolidation of the material usually accompanies its disintegration, the small broken pieces becoming washed into the interspaces of the bed. The same thing takes place where the separate fragments of material in a bed are of unequal size.

In the Leeds experiments it was found that contact bed No. 8, treating septic tank liquor, had its capacity reduced within six months from 29,500 gallons to 10,700 gallons, and this notwithstanding that the material below the upper 2 inches was still comparatively clean.

The bed was rested for six weeks, and the material turned over, with the result that on restarting the capacity was found to be 26,900 gallons. The material in this bed was furnace clinker of $\frac{1}{8}$ inch to $\frac{3}{8}$ inch diameter.

Much the same result was noticed during the filtration of lime-precipitated liquor at Leeds in a contact bed. The original water capacity of this bed, on March 24th, 1899, was 55,700 gallons ; on October 20th, 1899, after rather over seven months' working at three fillings per 24 hours, it had fallen to 21,600 gallons. Here again the material (clinker of $\frac{5}{8}$ inch to 1 inch diameter) below the upper few inches was found to be fairly clean, though much consolidated.

It was concluded that the loss of capacity in both cases was due very largely to consolidation of fine material of uneven size, and our own observations of these beds bear this out.

In another case—Hampton—where very much finer material was used, the same thing was observed. Tertiary bed No. 2, composed of boiler furnace clinker under $\frac{1}{4}$ inch diameter, including dust, after being in use for five years, became so consolidated that much difficulty was experienced in getting the secondary bed effluent into it. The bed was then simply turned over, and a considerable increase of capacity resulted. From the appearance of the material before it was turned over (which although clean, was closely bound together), it was evident that the greater part of the loss of capacity was due to the consolidation of the material rather than to clogging from suspended matter.

Beds of very fine material, as in this case, are undoubtedly more liable to consolidation than beds of medium sized or large material. In some beds of the same kind at Devizes, we observed that the fine material (which also included dust), although fairly clean, was so closely bound together that the liquid of one filling had not time to run away before the next filling was due, with the result that putrefaction set up in the body of the bed.

(3) *Deposition of Colloidal Matter.*

114. The extent to which colloidal matter affects the capacity of filter beds has not been fully investigated, but we are satisfied that in some cases it is serious. Dr. Fowler was, we believe, one of the first to investigate the matter in this country, and it has recently been the subject of investigation by Dr. Owen Travis at Hampton, and Messrs. O'Shaughnessy and Kinnersley at Birmingham.

(4) *Growth of Organisms.*

115. If a piece of clean filtering material is taken out of the interior of a matured contact bed and scraped, its surface will be found to be covered with a jelly-like material, which, under the microscope, is seen to contain enormous numbers of bacteria. This material possesses the power of absorbing oxygen rapidly and liberating carbon dioxide. It is probable that it is the living matter bound up in this jelly which gives the bed power to break down and oxidise the organic matter of impure liquids, but little is known about its precise nature and manner of action.

Several witnesses have expressed the view that the growth of organisms is one of the causes of loss of capacity in a contact bed.

In regard to this point Dr. Fowler stated :—

Fowler, 22803.

> " This (growth of organisms) is at once the cause of increased efficiency in " the bed, and of loss of capacity. On examining the material of a contact bed " in active condition, every piece is seen to be coated over with a slimy growth. " If this is removed it soon dries to a stiff jelly, which can be cut with a knife. " Under the microscope masses of bacteria and zoogloœa will be found to be " present. If placed in a tube containing air, and connected with a manometer, " the jelly will rapidly absorb all the oxygen and produce carbon dioxide.
>
> " This action will sometimes produce a vacuum of several inches of mercury. " There is little need, therefore, to force air into a bed, as the natural interchange " of gases which takes place is sufficient for adequate aeration. As a matter " of fact, there is always a large amount of oxygen to be found at the bottom of " a bed in good condition. The behaviour of the bacterial jelly appears to afford " the clue to the successful working of bacteria beds. By working them at a high " speed—*i.e.*, filling them frequently in the day, without long periods of rest— " the effluent may remain good, but the bacterial growth so rapidly increases " that the bed becomes too spongy, and will not allow the water to drain away. " Here, too, is the explanation of the fact that, within certain limits, decrease of " capacity is accompanied by increase of efficiency.
>
> " This decrease of capacity may, however, become so great as to outweigh " the advantage of increased efficiency. A long period, say one or two weeks' " rest, must then be given to the bed.
>
> " These rests should not exceed a fortnight at most, as the bed then tends to " dry up, and the activity of the organisms diminishes.
>
> " It is therefore important that the decrease of capacity should not be " allowed to become excessive before resting, or it may not be possible to com- " pletely recover the loss during the time of rest."

(5) *The Volume of Liquid passed on to the Bed.* (6) *Insufficient rest.* (7) *Inefficient drainage.*

116. It is evident that, for physical reasons alone, the working capacity of a contact bed must be influenced to some extent by the actual volume of liquid treated. If, for instance, two exactly similar contact beds, filled with unmatured material of the same size, are fed with pure water, one being given eight fillings and the other two fillings per day, the former, although not losing capacity in the absolute sense, will take rather less water at each filling than the latter, owing to the less time allowed for drainage between the fillings.

We do not suggest that the water held in a clean and unmatured bed by capillary attraction, after the bed is emptied, has a serious practical effect upon the working capacity of a bed; but with a matured contact bed containing jelly-like masses of bacteria as well as sewage suspended matter in a very spongy state, the time allowed for drainage becomes a question of importance, and the volume of liquid dealt with, in practice, affects the capacity of contact beds. A rather larger quantity of filtering material would, for instance, be advisable at a sewage works, where two volumes of weak sewage were to be treated in contact beds, than at another where one volume of sewage, of twice the strength, had to be dealt with.

117. The value of rest to a contact bed in helping it to maintain its water capacity is well known. We may cite two cases; one relating to the treatment of a manufacturing sewage (Leeds), and the other to the treatment of a purely domestic sewage (Hampton).

Leeds.—During the experiments upon the filtration of Leeds crude sewage, the primary bed, which started on October 2nd, 1897, with a water capacity of 83,000 gallons, had been reduced by February 2nd, 1898, to 45,000 gallons capacity. After a fortnight's rest its capacity was again measured, and found to be 56,000 gallons, or an increase of 11,000 gallons.

A similar increase of capacity followed subsequent rests.

Hampton.—At Hampton, No. 2 primary bed started in the early part of 1899 with an estimated water capacity of approximately 43,500 gallons, and was found on February 3rd, 1903, to have a capacity of only 8,637 gallons. On September 23rd, 1904, after a fortnight's rest, its capacity had risen to 12,965 gallons.

A gain of capacity in contact beds, by giving them rest, has been commonly noticed ever since they were first brought into use by Mr. Dibdin. For some time the cause of the gain was assigned to the biological digestion of the suspended matter caught in the material of the filter. A part of the gain in capacity which takes place during rest is no doubt due directly to this cause; but we think that much is due indirectly to the digestion tending to make the organic matter in the bed of a more granular and less spongy character. The ultimate gain in capacity is due to the water being able to drain away. It was shown, by Colonel Harding and Mr. Harrison at Leeds, that the deposit in a primary contact bed which had caused that bed to lose capacity contained something like 90 per cent. of water.

It must be remembered, however, that the gain in capacity which results from the resting of a clogged bed is generally only of a temporary character, a short rest of, say, a fortnight, serving for little more than to shrivel up the spongy and gelatinous matter in the interspaces of the bed. In many cases it has been observed that such matter returns to its original spongy state soon after the bed has been restarted. If a bed could be rested for a very long time, the sewage matter would become permanently granular through oxidation; but this is not practicable on a large scale, and as it would possibly result in the bed losing its maturity, it is important not to allow a contact bed to become so seriously clogged as to necessitate a prolonged rest.

As we have already intimated, it is important that the drainage should be efficient. Unless a bed is so constructed as to allow of proper drainage it will inevitably suffer rapid loss of capacity. Moreover its oxidising power will be impaired.

(8) *Suspended Matter in Liquid.*

118. Where the greater part of the suspended matter in the incoming liquid is allowed to find its way into the body of the material, the loss of capacity tends to vary in direct proportion to the amount of suspended solids in the sewage or tank liquor which is being treated. If very fine material is used in a bed, or if a bed of medium sized material is coated with a layer of very fine material, a large proportion of the suspended matter is caught upon the surface.

There is a large amount of experience showing that primary contact beds lose capacity at a greater rate than secondary beds, and we think there can be no doubt that this is largely due to the fact that the primary bed usually receives considerably more suspended matter. At the same time the facts that the suspended matter in a primary bed effluent is of a somewhat different character to the suspended matter in a tank liquor or a crude sewage, and that there is less colloidal matter in a primary bed effluent, would, to a lesser extent, account for the difference.

119. The following table shows the loss of capacity, per million gallons of liquor treated, at places which have been under our own observation, where septic tank liquor was treated on *primary* contact beds of medium sized material :—

Place.	Suspended matter in the liquor treated. (Hourly samples taken in dry weather.)	Age of beds in months.	Average number of times beds were filled per day.	Estimate of total number of gallons treated.	Loss of capacity in gallons.	Rate of loss of capacity per million gallons.
Guildford - - -	15·9	46	2·0	223·8 millions	108,794	486 gallons
Exeter (Main Works)	12·5	37	1·62	2,056 millions	750,750	365 gallons
Andover - - -	11·1	38	1·2	96 millions	79,600	828 gallons
Exeter (Old Works) -	8·2	109	1·64	196·2 millions	39,670	202 gallons
Slaithwaite - -	7·1	84	2·0	226·2 millions	33,755	149 gallons

With the exception of Andover, the loss of capacity per million gallons was, approximately, in proportion to the amount of suspended matter put upon the beds. The high rate of loss of capacity at Andover is accounted for by the fact that the material in the beds disintegrated to such an extent as to cause the surface level to sink considerably.

120. In connection with this matter we may refer to our Accrington * experiment. In that experiment two pairs of contact beds were run side by side for rather more than a year, one pair receiving two fillings per day of septic tank liquor, and the other pair receiving four fillings per day of the same tank liquor diluted with an equal volume of water. Both beds, therefore, received equal aggregate amounts of suspended matter. The capacity measurements throughout this time were as follows :—

	Primary bed treating septic tank liquor undiluted.	Secondary bed treating septic tank liquor undiluted.	Primary bed treating septic tank liquor diluted.	Secondary bed treating septic tank liquor diluted.
	Gallons.	Gallons.	Gallons.	Gallons.
May 3rd, 1905 (before starting) -	1,170	1,035	1,185	1,070
October 25th, 1905 - - -	810	1,080	770	940
June 6th, 1906 - - - - -	735	1,030	780	950

During this period, therefore, the two primary beds (of coarse material) lost capacity at, approximately, the same rate, the loss (435 gallons) in the primary bed treating the one volume of undiluted tank liquor being slightly greater than the loss (405 gallons) in the primary

* *See* pp. 110-117 and also Appendix IV.

bed treating the two volumes of diluted tank liquor. Even this small difference is explained by the fact that rather more than the proper proportion of suspended matter was, on the average, washed out of this bed, as the primary bed treating diluted tank liquor was emptied twice as frequently as the other. The average suspended matter in the effluent from the primary bed treating the one volume of undiluted tank liquor during the period was 6·3, and in the effluent from the primary bed treating the two volumes of diluted tank liquor 3·6 parts per 100,000. As the two primary effluents were discharged on to the two secondary beds (of fine material), the effect of the suspended solids was shown in these also, the difference in rate of loss of capacity being still further accentuated there by the fact that the secondary bed treating diluted tank liquor, unlike the primary bed, retained rather more than its proper proportion of suspended matter. The suspended matter in the effluent from the secondary bed treating undiluted tank liquor averaged 4·2, and in the effluent from the secondary bed treating diluted tank liquor 1·7 parts per 100,000. It is obvious, therefore, that, at any rate, the greater part of the disproportionate loss of capacity in the secondary bed treating the two volumes of diluted tank liquor was due to the fact that this bed received rather more suspended matter than the other secondary bed, and also held rather more back.

In June, 1906, the method of working the beds was altered. One set of beds then received two fillings per day of septic tank liquor undiluted, and the other set two fillings per day of septic tank liquor diluted with an equal volume of town's water. The first pair therefore received twice as much organic impurity, *including twice as much suspended matter*, as the second.

As will be seen from the following capacity measurements, the primary beds receiving the undiluted tank liquor soon began to lose capacity.

——	Primary bed treating septic tank liquor undiluted.	Secondary bed treating septic tank liquor undiluted.	Primary bed treating septic tank liquor diluted.	Secondary bed treating septic tank liquor diluted.
	Gallons.	Gallons.	Gallons.	Gallons.
June 6th, 1906 - - -	735	1,030	780	950
February 18th, 1907 - -	640	970	750	890

During this second period of working, the primary bed receiving one volume of undiluted tank liquor lost 95 gallons of capacity, while the primary bed receiving one volume of diluted tank liquor lost only 30 gallons. The average quantities of suspended matter entering and leaving the two primary beds for the period were as follows :—

——	Primary bed receiving one volume of septic tank liquor undiluted.	Primary bed receiving one volume of septic tank liquor diluted
	Parts per 100,000.	Parts per 100,000.
Average quantity of suspended matter going on to bed -	14·1	7·3
Average quantity of suspended matter coming out of bed	7·7	3·7

It might have been expected that the loss of capacity in the secondary bed treating the diluted tank liquor would have been only half the loss of capacity in the secondary bed treating the undiluted tank liquor. It will be seen, however, that the loss of capacity in the secondary beds was the same in each case. The suspended solids in the effluent from the secondary bed treating the undiluted tank liquor averaged 5·0 parts per 100,000,

but the suspended solids in the effluent from the secondary bed treating the diluted tank liquor, so far as we could judge from the centrifuge figures (which, however, can only be taken as approximate), were about one-third of this, the actual figures being as follows :—

——	Secondary bed receiving one volume of septic tank liquor undiluted.	Secondary bed receiving one volume of septic tank liquor diluted.
	Parts per 100,000.	Parts per 100,000.
Average quantity of suspended matter going on to bed -	7·7	3·7
Average quantity of suspended matter coming out of bed	5·0	1·7 approx.

In both periods of working (May 3rd, 1905, to June 6th, 1906, and June 6th, 1906, to February 18th, 1907), the loss of capacity in every one of the four beds (primary and secondary) ran concurrently with the amount of suspended matter held back by the bed.

Campbell, 21665. Harrison, 22016. Valentine, 22462. Wike, 23571.

121. A contact bed loses capacity rapidly at first, and subsequently at a diminished rate. Evidence in regard to this was given by Mr. Campbell, of Huddersfield, Mr. Harrison, of Leeds, Mr. Valentine, of Oldham, and Mr. Wike, of Sheffield, and others.

At Huddersfield the period of rapid loss in the case of the primary bed was within the first five months, and in the case of the secondary bed within the first twelve months. At Leeds it seems to have been within the first nine or twelve months ; at Oldham within the first twelve months ; at Sheffield, for the primary contact bed, within the first six months, and for the secondary bed, within the first twelve months.

We may also refer to the experimental Roscoe beds at Manchester which, after losing capacity for some time, eventually reached an equilibrium, and from then onwards maintained a constant water capacity so long as the suspended matter accumulating on the surface was periodically removed. These beds were filled with chemically precipitated sewage, which usually contains less colloidal matter than settled sewage or septic tank liquor.

It does not appear that any rule can be deduced as to the length of the period during which capacity is lost rapidly. It would, no doubt, partly depend both upon the rate of filtration and upon the amount of suspended matter reaching the bed.

How to Diminish the Rate of Loss of Capacity.

122. The capacity of a contact bed is best maintained by :—

Preventing as far as possible the access of suspended or colloidal matter to the bed ;

Using materials which are not liable to disintegrate ;

Using for the body of the filter material of even size, and in the form of cubes or spheres rather than flakes.

Allowing thorough and efficient drainage ;

Not over-working the bed ;

Giving periodical rests ;

Filling and emptying the bed in such a way as not to disturb the material.

The access of suspended matter to a contact bed is, in most cases, the chief cause of loss of capacity, and no doubt the rate of loss can be greatly lessened by carefully eliminating the suspended solids from the sewage before filtration.

Some small experimental filters at Kingston, fed with precipitation liquor, which had been produced by the "A.B.C." process, maintained their capacity in a remarkable manner. By this process a tank liquor is obtained containing a very small amount of suspended solids.

Even the best known means for removing the suspended matter by preliminary treatment does not get rid of it entirely, and it is generally advisable to provide a layer of fine material in the upper few inches of the bed, so as to prevent, as far as possible, the suspended matter from gaining access to the body of the bed.

Experience may show that it is economical to adopt some intermediate method of removing suspended matter from tank liquors. At Birmingham, Dortmund tanks are used for this purpose, and at Leeds, Chester, Ilford, and Guildford, mechanical straining has been tried. The latter method, however—as carried out at those places—has not been satisfactory.

The question whether it is more economical frequently to wash or renew the material in contact beds, or to remove the greater portion of the suspended matters from the liquor before it is treated, and to wash the beds less frequently, depends primarily on local circumstances.

Of the preliminary processes for removing suspended matter from sewage, chemical precipitation followed by either quiescent or continuous flow settlement is undoubtedly the most efficient of those at present known; but it involves a larger annual cost in most cases than settlement by means of settling or septic tanks, and there is a larger quantity of sludge to be dealt with.

Washing of Filtering Material.

123. The evidence shows that in many cases it is practicable and economical to wash filtering material which has become clogged. The cost varies according to local circumstances, and the following instances may be cited.

At *Burnley*, the material of several clogged beds was washed by means of an inclined rotary screen, 10 feet by 4 feet, fixed at a suitable elevation and so constructed as to be easily capable of removal from bed to bed as required. The arrangement admitted of washing, grading, and screening the material (clinker): the washing was effected by the tank effluent: and the power was supplied by a portable engine. Pickles and Ross, 20785.

The cost of these operations was at the rate of 1s. per cube yard of material, which covered excavating, packing troughs, wheeling, and screening and washing not only the material excavated but also the additional material required to take the place of the old material rejected (about 10 per cent.) and filling it into the bed.

At *Leeds*, Mr. Harrison, the chemist to the Corporation, washed 1,020 cubic yards of material, by hand labour with screens and a heavy flow of water, at a cost of 2s. 5d. per cube yard. Harrison, 22017.

At *Manchester*, the washing of filtering material has been done on a very large scale, and is carried on continuously. The method employed is to pass the material from a sump to a jigging screen of $\frac{1}{4}$-inch mesh, over which are fixed a series of horizontal water sprayers. The material rejected by this screen is further graded by passing over a fixed 2-inch mesh screen. The material which passes through the $\frac{1}{4}$-inch screen falls on to an inclined fixed screen of $\frac{1}{8}$-inch mesh. All material above $\frac{1}{4}$-inch is replaced in the primary filters; that between $\frac{1}{4}$-inch and $\frac{1}{8}$-inch will be used for the surface of the secondary contact beds, when these are constructed. Settled sewage is the liquid used in the washing.

The total cost of removing, washing, screening and replacing in beds and making up to original level with new material at Manchester, is 1s. 6d. per cube yard. This does not include cost of washing machinery.

At *Birmingham*, 20,000 cubic yards of material were dealt with in the following manner: the material was dug out of the beds by manual labour and conveyed in tip wagons to a high platform by an electrically-driven winch; it was then passed through revolving screens and simultaneously washed with sewage.

The cost of removing, washing, screening and replacing material in the beds was at the rate of 11d. per cube yard. With the additional material required to make up to original level of bed, the total cost was 2s. 2½d. per cube yard. This does not include the cost of the washing plant.

At the *Beddington* and *South Norwood* sewage works of the Corporation of Croydon, filtering material has been washed on a large scale. The work was done by hand labour, and the cost of washing and replacing the material in the beds was approximately 1s. 2½d. per cube yard at Beddington, and 1s. 6d. per cube yard at South Norwood.

At *Andover*, the cost of washing and replacing material by hand labour, with a special apparatus devised by Mr. R. W. Knapp, the surveyor, was about 2s. 4d. per cube yard. This covered the initial cost of the washing apparatus.

At *Hampton*, washing is effected by means of a machine driven by compressed air. The cost of removing old material, screening, washing and replacing in bed, and providing new material to make up deficiency (25 per cent.), is 1s. 9¾d. per cube yard.

Campbell, 21852. At *Huddersfield*, the borough engineer found that the cost of washing material was not less than 4s. 6d. per cube yard. No information was given as to the method employed.

124. The cost of washing, etc., at the several places mentioned (except Huddersfield) is summarised in the following tables:—

MATERIAL WASHED BY MACHINERY.

Name.	Nature of liquid treated by beds.	Average amount of suspended matter in liquid going on to beds (parts per 100,000).	Time beds had been in use.	Nature and size of material.	Quantity of material dealt with (cube yards).	Cost per cube yard of washing operations, including making beds up to original level with new material, but excluding cost of washing plant and maintenance charges on same.	Cost per acre, 3 feet deep, of washing operations, including making beds up to original level, with new material, but excluding cost of washing plant and maintenance charges on same.	Percentage of original material replaced in bed.	Cost per cube yard of new material.	Remarks.
						s. *d.*	£ *s.* *d.*			
Burnley - -	Septic tank liquor	5 to 6	3½ years	Clinkers (⅛″ to ½″)	3,350	1 0	242 0 0	60 per cent.	—	
Manchester -	Septic tank liquor	5 to 6	4 to 5 „	Clinkers (medium to coarse)	A very large quantity	1 6[b]	363 0 0	70 per cent. to 75 per cent.	½″ to 2″—2*s.* 6*d.* to 3*s.*; over 2″ 3*s.* to 3*s.* 6*d.*[a]	[a]Delivered in the beds. [b]Final disposal of rejected material not included in this figure.
Birmingham -	Septic tank liquor	—	4 „	Clinker, Coke (fairly coarse)	20,000	2 2½	534 0 0	80 per cent.	6*s.* 6*d.*[c]	[c]New material—broken stones.
Averages - -	—	—	4 years	—	—	1 6¾	380 0 0	71·25	—	

MATERIAL WASHED BY HAND

Hampton - -	Crude sewage	48·5	2 to 4 years.	Clinker (medium to coarse)	260	2 6¾	620 0 0	Primary beds 75 per cent. Secondary beds 65 per cent.	—	
South Norwood -	Screened sewage	Not known	4 „	Burnt ballast (medium to coarse)	1,640	1 6	363 0 0	—	—	
Beddington -	Septic tank liquor		3¾ „	Flint and clinker (coarse)	15,377	1 2½	292 0 0	No appreciable loss with flints.	—	
Andover - -	„ „	11·10[e]	4 „	Clinker (½″ size free from dust)	490	2 4[e]	564 0 0[d]	—	—	[d]Including cost of plant.
Leeds - - -	—	—	—	—	1,020	2 5	584 0 0	—	—	[e]Based on the three sets of average samples, taken October, 1904.
Averages - -	—	—	About 4 years	—	—	2 0	484 12 0	—	—	

It should be added that washed material has an enhanced value for filtration purposes, due in great measure to the fact that the softer and more friable portions of the original material, which have become broken down, are eliminated in process of washing.

125. We may mention here that other plans for restoring contact beds which have become clogged have come under our observation at Hartley Wintney, Hendon, and Oswestry.

At *Hartley Wintney* the contact bed material (gas works clinker) was simply turned over. The amount dealt with was 679 cube yards; one man was employed; and the cost amounted to only 5½d. per cube yard.

The beds had been in use about four and a half years when the material was turned over.

The increase in capacity due to this process was, however, quickly lost again.

At *Hendon*, the ballast on the percolating beds was reburned. The cost amounted to 3s. 6d. per cube yard; but this covered the sifting out of the small material, wheeling out the fine stuff and spreading it, and relaying drains, etc. The beds had been in use for sixteen years.

At *Oswestry*, the old material of the beds was so disintegrated as to render washing impracticable, and there was sufficient new material (screened cinders) lying on the site. The old material (cinders) was therefore discarded and the beds filled with new material. The quantity dealt with was 1,550 cube yards, and cost of removing and renewal amounted to 2s. 7½d. per cube yard. The beds had been in use for about four years.

Filtering Material in Contact Beds.

126. The materials in general use for contact beds are clinker and coke, and experience of other materials is not very great.

With percolating filters, however, many different materials have been used, and although the actual working of percolating filters is different from that of contact beds, the results are, to a large extent, applicable. At York, a quantitative experiment with septic tank liquor was made by us on a circular percolating filter 7 feet 8 inches deep and constructed in four segments—one of clinker, one of coke, one of slag, and one of broken brick—the material in each case being broken and riddled as nearly as possible to the same size; the bulk of the clinker was, however, distinctly smaller than the other three materials. The results showed that the best effluent was obtained from the clinker segment, that the coke and slag segments gave very similar effluents, but not quite so good as the effluent from the clinker segment, and that the effluent from the broken brick segment was lowest in the scale of purity. All four effluents were of good quality.

Watson 25004. At Hendon the late Colonel Ducat obtained a better effluent from clinker in a percolating filter 8 feet deep than from pebbles in the same bed. At Birmingham Mr. J. D. Watson found that for percolating filters gravel has too smooth a surface. Dr. George Reid also stated in evidence that "any hard, non-friable material of irregular shape and not too smooth a surface, and one which is not liable to disintegrate is satisfactory as a

Fowler, 22794. filtering medium for percolating filters."

The experience at Manchester, with regard to contact beds, has been that hard furnace clinker is the best material, being vesicular and yet permanent. Dr. Fowler, however, expressed the opinion that broken Staffordshire bricks, saggars and gravel, if properly sized, should do equally well.

It will be seen from the evidence that many witnesses have stated that substances like gravel, flints, or broken granite, are suitable as a filtering medium, but that, in most cases, tney have expressed a decided preference for the use of those materials which present the roughest and most irregular surfaces, such as clinker, coke, and saggars.

So far as our own experience goes, we should prefer, as a general rule, to use coke or good clinker in a contact bed in preference to other materials.* It is true that there is some evidence to the effect that rather better effluents can be obtained from contact beds of coke than from contact beds of clinker, but we think that this advantage is balanced by the tendency of the lighter material, coke, to shift slightly every time the bed is filled, and therefore to be more liable to disintegration.

* Broken "saggars" might be equally good, but we have had no experience of this material in contact beds.

In the choice of a filtering medium local circumstances must, of course, be taken into account. For example, there may be places at which a somewhat inferior material may be obtained at a very low price, and where it would be cheaper to renew the beds more frequently, or to provide a larger area of beds, than to pay the higher price for better material.

Probably most materials will purify sewage, but a larger quantity of smooth than of vesicular material would be required to produce equal purification.

127. Mr. W. J. Dibdin has lately advocated the use of large slabs of slate in primary contact beds, the horizontal layers of slate being separated from one another by cross pieces. He claims that crude sewage can be purified to a considerable extent in such beds, and that the sludge which accumulates in them can be periodically flushed out with water. Up to the present time we have had no experience of primary contact beds constructed in this way, beyond a single visit to Devizes where such beds were in use for the treatment of screened sewage. As a result of our inspection of the beds at Devizes, we came to the tentative conclusion that primary beds containing large slabs of slate must be regarded more as preliminary settling or septic tanks than as contact beds. As to the feasibility of washing such beds out, or as to the amount of digestion of sludge which takes place in them, we are unable to express an opinion.

Size of Material.

128. The smaller the size of material used in a contact bed the greater is the internal surface area exposed, and consequently the more intimate is the contact of the liquid with the material, the greater the purification, and the more efficient the arrest of the suspended and colloidal matter.*

The efficiency of a contact bed, however, depends very largely upon the admission of air to all parts of the filter during the time the bed is resting empty. Thorough and rapid drainage is therefore of the utmost importance.

For this reason, it is important that the material in a contact bed should not be *too* small, especially if the liquid to be treated contains an appreciable quantity of suspended matter, as some of this suspended matter will undoubtedly find its way into the interstitial spaces and prevent proper drainage of the bed. This was found to be the case with the fine beds at Devizes and Hampton.

At Devizes the contact beds were composed of very fine clinker broken to a diameter from $\frac{1}{4}$-inch downwards and including dust. Shortly after the beds were brought into operation, working at a rate of three fillings per day, it was found, on digging down into them, that the liquid of one filling had not drained away from the beds when the time for the next filling arrived. On examination it appeared that, although there was not actually a large quantity of sewage solids admixed with the filtering material, enough was present to bind the whole together, so that the bed drained away very slowly.

At Hampton the tertiary contact beds were composed of furnace clinker of $\frac{1}{4}$-inch or less, including dust, and after five years' work the material had settled into an almost solid mass, and the beds could only be filled with difficulty. The material, when turned out, presented a very similar appearance to that at Devizes, being closely bound together, although mixed with only a small proportion of sewage suspended matter.

129. If the liquid to be treated contained no suspended or colloidal matter, material as fine as medium sand would probably give the best results ; but if crude sewage were to be put upon this sand, the surface would become so clogged with sewage sludge in two or three fillings that the bed would be practically useless. The top layer would then have to be removed, or the bed would have to be rested until the sludge upon the surface had dried sufficiently to be raked off. Even if the top sand were constantly removed and replaced, it would be found, as at Hampton and Devizes, that some particles of suspended matter would penetrate into the interior of the bed, and that eventually the drainage of the bed would become defective.

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* Note.—See Biltz and Kröhnke, Berichte, vol. xxxvii., p. 1745 ; Fowler and Ardern, J. Soc. Chem. Ind., vol. xxiv., p. 483 (1905) ; Jones and Travis, Proc. Inst. C.E., vol. clxiv., paper 3599, p. 32 (Jan. 1906) ; O'Shaughnessy and Kinnersley, J. Soc. Chem. Ind., vol. xxv. (April, 1906); Johnston, J. Roy. San. Inst., vol. xxvii., p. 10 (1906).

In deciding upon the size of the material to be used, the amount of suspended matter in the liquid to be treated, must be considered. As a general rule, the greater the amount of suspended matter in the liquid the larger the material should be.

With a crude sewage containing 40 parts per 100,000 of suspended matter, the material will probably have to be from 3 inches upwards in diameter, and even then sludge will accumulate on the top.

With a septic tank liquor containing 8 to 10 parts per 100,000 of suspended matter, material of a diameter from $\frac{3}{8}$ to $\frac{5}{8}$ of an inch may probably be used effectively; while with a good precipitation liquor containing from 1 to 3 parts of suspended matter, the best results will probably be obtained from material as fine as $\frac{1}{4}$-inch diameter.

130. It is, however, impossible to make any but the most general statement as to the most suitable size of material for contact beds, as, in some cases, there may be special circumstances which affect the question, such as the character of the suspended matters, or the smoothness of the filtering material. The sizes we have suggested are based on the evidence which we have received and also on our experience of contact beds at the places named in the following statement :—

	Suspended matter in the liquor treated (approximate figures).	Nature of material.	Size of the material in the contact beds.
Crude Sewage.	Parts per 100,000.		
Hampton	48·5	Clinker.	Above 4″ diameter.
Leeds	35·0	Clinker and coke.	Above 3″ diameter.
Newton-le-Willows	30·0	Clinker.	Top 18″—$\frac{1}{2}$″ to $\frac{1}{4}$″ diameter. Body of filter, 2″ to 1$\frac{1}{2}$″ diameter.
Withnell	20·0	Clinker.	1″ to 1$\frac{1}{2}$″ diameter.
Maidstone	14·0	Clinker.	Above $\frac{3}{4}$″ diameter.
Settled Sewage.			
Oswestry	About 20.	House coke.	1$\frac{1}{2}$″ to $\frac{1}{2}$″ diameter.
Halton	11·0	Clinker and pebbles.	1″ to 2″ diameter.
Septic Tank Liquor.			
Leeds	18·0	Clinker.	$\frac{5}{8}$″ to $\frac{3}{8}$″ diameter.
Guildford	16·0	Burnt ballast.	$\frac{1}{2}$″ to 3″ diameter.
Hartley Wintney	15·0	Clinker.	$\frac{1}{2}$″ to $\frac{1}{8}$″ diameter.
Exeter (Main)	About 14.	Clinker.	$\frac{1}{2}$″ to 1″ diameter.
Andover	12·0	Clinker.	$\frac{1}{8}$″ to $\frac{1}{2}$″ diameter.
Exeter (St. Leonards).	8·5	Clinker and coke.	$\frac{1}{2}$″ diameter.
Slaithwaite	8·0	Clinker.	Top foot—$\frac{3}{8}$″ to $\frac{1}{3}$″ diameter. Body of filter, $\frac{3}{8}$″ to 1″ diameter.
Precipitation Liquor.			
Calverley	12 to 14.	Clinker.	$\frac{1}{4}$″ to $\frac{1}{2}$″ diameter.
Kingston (experimental beds)	2·0	Clinker and coke.	Coke bed, $\frac{1}{4}$″ to 1″ diameter. Clinker bed, $\frac{1}{4}$″ to $\frac{3}{8}$″ diameter.

Grading of Material.

131. From our own observations, and from the evidence, we are of opinion that, as regards the bulk of the material in the bed, grading is not necessary, and that much labour and expense have sometimes been incurred, to very little purpose, in too great a refinement of grading. A certain amount of grading is, however, always necessary. Over the drains of the beds, for instance, material of fairly large size must be laid in order to prevent choking. Again, in order to preserve the life of a contact bed, it is advisable to retain as much as possible of the suspended matter upon the surface of the material, and this seems to be best effected by using fine material for the top 6 inches or so.

We may refer particularly to the evidence on this question which was given by Mr. D. Cameron (2091); Mr. Baldwin Latham (4505); Colonel Harding (7165–6); Dr. P. F. Frankland (9985–6); Mr. Bolton (21145); Mr. J. Kershaw (21464); Mr. Campbell (21655); Mr. Harrison (22008); Dr. Fowler (22795); Mr. Wike (23652); Mr. Wilkinson (24286); Messrs. Willcox and Raikes (26182).

Amount of Sewage which can be Treated on Contact Beds.

132. The amount of sewage which can be treated on contact beds chiefly depends on the strength of the sewage, on the quality of effluent which it is required to produce, on the amount of suspended solids in the sewage, and on the size of the filtering material. The question is dealt with in the section headed "General Conclusions as to the Working Power of Different Types of Filter," p. 117.

PERCOLATING FILTERS.

Depth of Percolating Filters.

133. The question of the depth of percolating filters is one of far greater complexity than at first sight appears. At most places the depth has usually been determined by the levels. If plenty of fall has been available, deep filters have been constructed, while at places with little fall, the material has usually been laid out in the form of a shallow filter. In other words percolating filters have usually been constructed as deep as levels would allow. In some cases the advantage of deep filters over shallow filters has even been considered sufficient to justify the adoption of pumping.

It has thus been generally accepted that, in the case of percolating filters, the deeper the material the better the result obtained. That there were good grounds for this conclusion will be seen from the following evidence.

At Accrington, in 1897, Mr. C. J. Whittaker, experimenting upon the depth of filtering material necessary for the purification of open septic tank liquor by means of the Whittaker and Bryant percolating filters, compared the results obtained from filters 6 feet and 9 feet deep, both constructed of the same coarse material and both receiving the same quantity of tank liquor *per square yard.* Mr. Whittaker found that the 9 foot bed gave better purification and higher nitrification than the 6 foot bed.

At Leeds, in the year 1900, Colonel T. W. Harding and Mr. W. H. Harrison, in their experiments upon the continuous filtration of crude sewage, touched upon the same point. In one of these experiments, which lasted for six months, Leeds crude sewage was allowed to trickle continuously through three filters one after another, one object of the experiments being to ascertain the purifying effect of each separate filter. The filters were 3′ 6″, 2′ 6″ and 2′ 6″ deep respectively, so that the total depth of the material, which consisted of coarse coke, was 8′ 6″. The average analyses of the effluents from each filter, from March to June, 1900, were as follows :—

Grains per gallon.

———	Crude Screened Sewage.	First Filter 3′ 6″ deep.	Second Filter 2′ 6″ deep.	Third Filter 2′ 6″ deep.
Free Ammonia - - -	2·36	1·58	1·15	0·83
Albuminoid Ammonia - -	1·04	0·59	0·43	0·29
Oxygen absorbed from permanganate in 4 hours.	8·90	4·37	2·78	1·93
Nitrogen as nitrates - -	—	—	—	0·14
Total solids - - - -	123·2	87·6	74·0	7·17
Suspended solids - - -	44·2	19·2	7·9	7·7

Another experiment was made by Mr. Carter Bell, at Salford, during the years 1900 and 1901, on the depth of medium-sized material necessary for the purification of Salford precipitation liquor. In this experiment three percolating filters 8 feet, 5 feet, and 3 feet deep, all constructed of medium-sized clinker, received precipitation liquor at the same rate *per square yard.* Typical analyses of the effluent are given by Mr. Carter Bell as follows :—

Grains per gallon.

	Shallow filter 3 feet deep.	Medium filter 5 feet deep.	Deep filter 8 feet deep.
Free Ammonia - - - - - - - -	2·6	2·4	2·2
Albuminoid Ammonia - - - - -	0·20	0·18	0·14
Oxygen absorbed from permanganate in 4 hours -	1·1	0·8	0·5
Nitrogen as nitrates - - - - - -	0·84	1·10	1·30
Total solids - - - - - - - -	65·0	66 0	65·0
Koch's gelatine and incubation test - - - -	Fairly satisfactory.	Satisfactory.	Very satisfactory.

At Horfield, Mr. F. W. Stoddart, experimenting with two filters of coarse clinker, one 7′ 6″ deep and the other 3′ deep, came to the conclusion that with an equal flow *per square yard* the deep filter gave the better results.

134. There were no doubt many other experiments of the same kind, showing that, when treating the same amount of sewage per square yard, the deeper the filter the greater is the purification effected. These experiments, however, do not show whether it is better to arrange a *given* quantity of material in the form of a deep or of a shallow percolating filter, and so far as we are aware no systematic experiments on the treatment of sewage or sewage liquor upon filters of different depths at equal rates *per cube yard*, instead of *per square yard*, were carried out until our observations were begun at Horfield and Ilford.

Horfield Experiments.

135. At Horfield, experiments were made in the years 1904–5, upon two filters of coarse clinker, one 7′ 5″ deep and the other 3′ deep, upon each of which quantities of Horfield precipitation liquor were treated at approximately the same rate *per cube yard* per day for ten months. Both filters were fed by means of Stoddart trays. The deep filter had a cubic content of 284 cube yards and the shallow filter of 27·56 cube yards.

The results showed that there was little to choose between the two effluents, though on the whole the effluent from the deep filter was slightly the better. At the same time, though the experiments showed that a coarse shallow filter (3 feet in depth) can quite well be made to give satisfactory results in the treatment of a precipitation liquor like that at Horfield, they also indicated that with coarse material, where the levels allow of it, a deep filter is on the whole preferable to a shallow one, especially where a strong liquor is being dealt with, since faults of distribution are toned down more.

Ilford Experiments.

136. At Ilford, a similar experiment with two very small percolating filters fed by means of Stoddart trays was made in 1903–4. The filters had the following dimensions :

Deep filter 12 feet by 9 feet and 6 feet deep.

Shallow filter 12 feet by 9 feet and 3 feet deep.

The material used was coke, from $1\frac{1}{2}$″ to 3″ in diameter. Both filters were fed with septic tank liquor at the rate of 125 gallons per cube yard per day. The effluents obtained from both filters were usually non-putrescible, though not of high quality, the deep filter effluent being rather the better of the two.

In order to improve the distribution, the filters were to some extent remodelled in the early part of 1907 ; that is to say, the distributors were levelled and the upper layers of coarse coke were replaced by finer coke ($\frac{1}{4}$″ to $\frac{3}{8}$″ diameter) to the depth of six inches on the deep filter and 3 inches on the shallow filter. Immediately below these fine layers, there were four inches in the deep filter, and two inches in the shallow filter, of medium sized coke.

From April 15th to June 28th, 1907, the filters were brought to maturity with gradually increasing quantities of septic tank liquor. During the time of the actual experiment, which lasted from June 1st, 1907 to January 20th, 1908, the quantities of septic tank liquor treated were as follows :—

On the deep filter (12′ × 9′ × 6′)—3,000 gallons, or 125 gallons per cube yard per 24 hours.

On the shallow filter (12′ × 9′ × 3′).—1,500 gallons, or 125 gallons per cube yard per 24 hours.

Between these dates, ten corresponding samples of septic tank liquor and of both filter effluents were drawn. The average figures for the analysis of the septic tank liquor were as follows :—

Septic Tank Liquor.

Parts per 100,000.

——	Maximum and minimum figures.	Average figures.	Number of estimations.
Total nitrogen	4·95 – 8·40	6·75	10
Oxygen absorbed from permanganate at once	1·17 – 4·39	3·34	10
Oxygen absorbed from permanganate in four hours	5·54 – 8·64	7·43	10
Suspended solids	5·3 – 9·2	6·9	10
Volatile matter in suspended solids	4·2 – 6·9	5·4	10

The calculated strength* of this liquor is 78·7, or after allowing for the abnormal ratio of the figure for oxygen absorbed at once to the figure for oxygen absorbed in four hours, 67·6.

The following table shows the average figures of the analysis of both effluents, with and without suspended matter :—

Effluents.

Parts per 100,000.

——	Analysis of sample containing suspended solids.		Analysis of sample after filtration through paper.	
——	Deep filter effluent.	Shallow filter effluent.	Deep filter effluent.	Shallow filter effluent.
Number of samples included in the average	10	10	7	7
Ammoniacal Nitrogen	2·92	3·55	2·93	3·54
Albuminoid Nitrogen	0·47	0·47	0·25	0·28
Total Organic Nitrogen	0·79	0·84	—	—
Nitrous Nitrogen	0·13	0·15	0·13	0·15
Nitric Nitrogen	1·94	1·35	1·94	1·35
Total Nitrogen	5·76	5·64	—	—
Oxygen absorbed at once	0·86	0·86	0·49	0·58
Oxygen absorbed in 4 hours	3·12	3·09	1·71	2·11
Incubator test (Scudder)	All passed.	8 passed, 2 failed	—	—
Incubator test (by smell)	All passed.	9 passed, 1 failed		
Dissolved Oxygen taken up in 48 hours	2·05	1·74	0·65	0·79
Dissolved Oxygen taken up in 5 days	6·62	6·49	1·49	1·90
Solids in suspension	6·40	5·10	—	—
Volatile matter in solids	4·60	3·80	—	—
Solids by Centrifuge (Vols.)	73·0	60·2	—	—

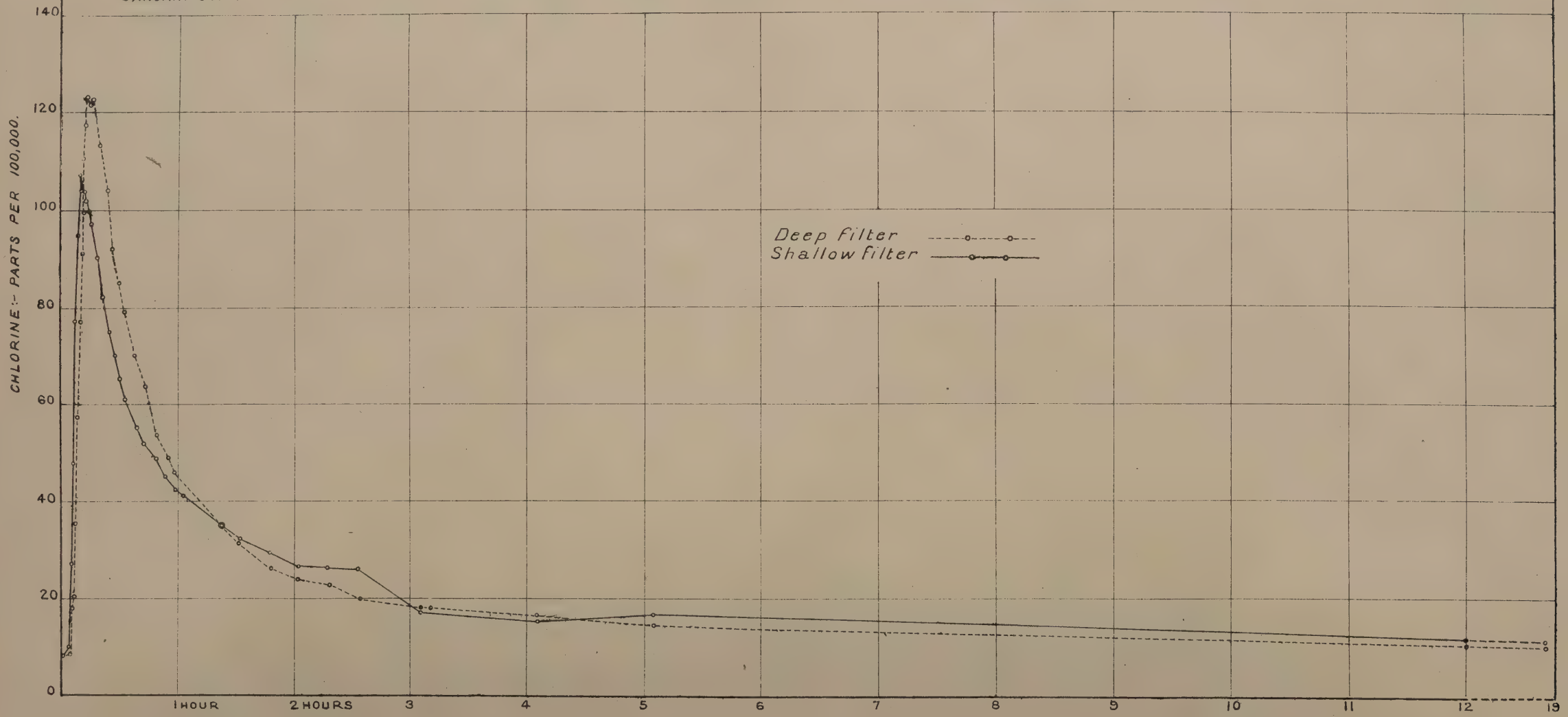
Apart from suspended solids, both effluents were of moderate quality, that from the deep filter being slightly better than that from the shallow filter as regards ammoniacal nitrogen and nitric nitrogen, the figures otherwise being very much alike.

* Strength means the number of parts by weight of oxygen required to oxidise 100,000 parts, arrived at on the basis of the formulæ suggested by Dr. McGowan—*see* p. 16 of this Report, and Dr. McGowan's Memorandum in Appendix IV.

DIAGRAM 1.

CURVES SHEWING THE RATES OF FILTRATION THROUGH TWO COARSE PERCOLATING FILTERS OF DIFFERENT DEPTHS AT ILFORD, AS TESTED QUANTITIVELY WITH A SOLUTION OF SALT.

(EACH SMALL CIRCLE REPRESENTS A CHLORINE ESTIMATION.)



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The following table showing the percentage purification obtained on the tank liquor, calculated in various ways, brings out the similarity :—

	Deep filter.	Shallow filter.
Calculated percentage purification on atmospheric oxygen used up (strength of septic tank liquor taken at 78·7). - - - -	74·6	71·8
*Units of purification on this basis (including suspended solids) -	7,339	7,063
Calculated percentage purification on atmospheric oxygen used up (strength of septic tank liquor taken at 67·6) - - - -	70·4	67·2
*Units of purification on this basis (including suspended solids) -	5,949	5,678
Calculated percentage purification, leaving out suspended solids (strength of septic tank liquor 78·7) - - - - - -	86·3	81·4
Calculated percentage purification, leaving out suspended solids (strength of septic tank liquor 67·6) - - - - - -	84·0	78·4

A little more work, *i.e.*, oxidation, was thus obtained from the deep filter per cube yard than from the shallow filter, but the difference was only slight, such as might be accounted for by the fact that imperfect distribution is more liable to affect the purification in a shallow filter than in a deep filter.

137. *For practical purposes we think the conclusion is justified that, within somewhat wide limits of depth, and given ample aeration and good distribution, the same amount of work can be got out of a cube yard of coarse material whether it is arranged in the form of a deep or of a shallow percolating filter.*

Rate of flow through Ilford filters.

138. With a view to ascertaining the relative rates of flow through the two filters the following experiment was made.

On January 9th, 1908, a strong solution of common salt was added to the septic tank liquor as it passed on to the two filters, samples of the effluent being taken at short intervals until almost all the salt had worked through the filters, a period in this case of about 19 hours.

The quantity of chlorine was then estimated in each sample.

It cannot be taken for granted that the passage of a solution of common salt through a filter is exactly similar to the passage of sewage impurity which is partly in true solution, partly colloidal, and partly in suspension. As sewage impurity passes through a filter it undergoes change, whereas the passage of a solution of common salt may be regarded for practical purposes as merely physical ; further, one may reasonably assume that sewage impurities are held up in the filter for a longer period of time.

The figures for the two filters were nearly alike throughout the experiment, but during the first hour a rather greater proportion of salt came through the deep filter, although, at the very beginning, the salt issued more quickly from the shallow filter. The figures are plotted out on Diagram I.

These experiments suggest that, given good distribution and ample aeration the extent of the purification effected by a percolating filter depends upon the length of time during which the liquor is in contact with the material, or, perhaps more correctly, upon the proportion of highly purified sewage in the effluent (*i.e.*, sewage which has taken hours to pass through the filter) to the proportion of sewage which has passed through more rapidly by following a much less circuitous route.

The three important factors which govern the rate of percolation are :—

(1) The kind of material, *i.e.*, whether the surface is rough or smooth ;

(2) The size of the material ; and

(3) The state of the filter as regards the bacteria and growths attached to the material, and also as regards worms, larvæ, etc.

* As to the meaning of the term "units of purification" *see* p. 107 of this Report.

Influence of the Nature of the Filtering Material.

139. We may refer to three experiments relating to the purification effected on the same sewage liquor by different filtering materials, all graded to be as nearly as possible of the same size.

In 1903, a circular filter, consisting of four kinds of material arranged in segments entirely cut off from each other by partition walls, was constructed by Mr. A. Creer at the York Sewage Works. The particulars of this filter, which was started on April 29th, 1903, were as follows :—

Diameter - - - - - - 100 feet.
Depth of material - - - - - 7 feet 8 inches.

Materials.

First Segment - - - - - 1,492 cube yards.
Clinker - - - - - $1\frac{1}{2}$ ins. to $3\frac{1}{2}$ ins. diameter.
Second Segment - - - - 312 cube yards.
Broken brick - - - - $1\frac{1}{2}$ ins. to $3\frac{1}{2}$ ins. diameter.
Third Segment - - - - 189 cube yards.
Blast furnace slag - - $1\frac{1}{2}$ ins. to $3\frac{1}{2}$ ins. diameter.
Fourth Segment - - - - 189 cube yards.
Gas coke- - - - - $1\frac{1}{2}$ ins. to $3\frac{1}{2}$ ins. diameter.

The filter was fed with septic tank liquor by a continuously revolving sprinkler, working automatically, and the rate of filtration on all four sections was approximately 360 gallons per square yard, or 140 gallons per cube yard, per day.

In June, 1904, we drew hourly samples of the effluent from each of the four segments over three complete days, the twenty-four samples from each segment being in each instance made up into a single sample for each complete day. As the three twenty-four hours' samples from each segment were very near to one another in chemical composition, only the average figures for each complete set of three days need be given here :—

Parts per 100,000.	Clinker.	Coke.	Slag.	Broken brick.
Ammoniacal Nitrogen - - - - - -	0·01	0·06	0·05	0·21
Albuminoid Nitrogen - - - - - -	0·10	0·10	0·12	0·15
Oxidized Nitrogen - - - - - -	2·90	2·47 approx.	2·32 approx.	2·48
Total Nitrogen - - - - - - -	3·18	2·95	2·72	2·88
"Oxygen absorbed" at 27°C. (80°F.) - *at once.*	0·38	0·49	0·63	0·63
„ „ „ - *in 4 hours.*	1·46	1·27	1.48	2·23
Dissolved Oxygen taken up in 24 hours at about 18°C. - - - - - - - - -	0·09	0·19	0.24	0·37
Dissolved Oxygen, in c.c. per litre - - -	0·65	1·32	1·72	2·57
Solids in suspension - - - - - -	2 15	1·22	1·73	2·00
Solids by Centrifuge (Vols.) - - - -	33·5	24·4	20·5	30·0
Ratio of Solids in suspension to Centrifuge solids-	1 : 15·6	1 : 20·4	1 : 17·3	1 : 15·0
Incubator Test (Scudder) - - - - -	All passed.	All passed.	All passed.	All passed.
„ „ (by smell) - - - - -	All passed.	All passed.	All passed.	All passed.
Smell when analysed - - - - - -	All good.	All good.	All good.	All good.

All these effluents were very good. It will be seen, however, that if we differentiate between them, the following is the order of merit for the different materials :—

(1) Clinker.
(2) Coke.
(3) Slag.
(4) Broken brick.

Between Nos. 2 and 3, the coke and the slag filter effluents, there is really no difference.

The foregoing experiment was made between June 27th and 30th, 1904, and we thought it well to test shortly afterwards—on July 19th—the comparative rates at which liquid coloured by fluorescine came through the different segments. The filtrates showed :—

	(*a*) Weak colour.	(*b*) Strong colour.
	Minutes.	Minutes.
1. Clinker	6	12
2. Coke	5	8
3. Slag*	8	9
4. Broken brick	2	2½

The order of the rate of percolation, as measured in this way, was thus the same as that of the purity of the effluent. Although the different filtering materials were all broken to be of the same size, the clinker was in reality somewhat smaller than the other three.

These experiments tend to confirm the view that the extent of the purification effected by a percolating filter depends upon the length of time taken by the sewage to pass through the filtering material, assuming always that the filter is properly aerated. Having regard to the vesicular nature of the clinker we should expect it to retard the passage of the sewage more than the broken brick, and hence to give a better effluent. The analytical results show that this was the case.

In his experiments at Hendon upon the filtration of crude sewage through medium-sized material, the late Colonel Ducat compared the results obtained from filters constructed of small pebbles and of clinker, both material being of the same size. The length of time taken by the sewage in passing through the clinker was, no doubt, greater than that taken by its passage through the pebbles, and the analytical results showed that better purification was obtained from the filter which was made of clinker.

In a laboratory experiment which was made by us at Leeds in the year 1900, we found that, using large smooth water-washed stones as the material in a filter five feet deep and one foot in diameter, and treating Leeds septic tank liquor at an approximate rate of about 70 gallons per cube yard per day, only traces of oxidised nitrogen appeared in the effluent after three or four months' working. Nitric nitrogen appeared in the effluents from the Whittaker filters at Leeds in a much shorter time than this. These latter filters were constructed of coarse coke or clinker and were fed with septic tank liquor at about the same rate, *i.e.*, 70 gallons per cube yard per day.

140. The results of these experiments may be summarised as follows :—

(1) Better results can be obtained per unit volume from a material with a rough surface than from a material with a smooth surface ; and

(2) The extent of the purification effected by a percolating filter varies with the average length of time taken by the sewage to pass through the filtering material, assuming that proper aeration of the filter is maintained.

Influence of the Size of the Material.

141. Although the experiments which we carried out at Ilford and Horfield showed that, with filters of coarse material, and given good distribution and ample aeration, a cube yard of filtering material will produce very similar results whether it is arranged in the form of a deep or of a shallow filter, it does not follow that this conclusion would apply to filters of medium-sized and fine material.

There are in reality three distinct classes of percolating filter in use for the purification of sewage or sewage liquors, viz. :—

(1) Percolating filters constructed of material coarse enough (say, over 2½″ in diameter) not only to give free access of air to its interior but also to allow the suspended matter in the liquid free passage through the whole depth of the filter. This is the class of filter to which the Ilford and Horfield experiments related.

* The amount of effluent coming from the slag segment was very small, owing to a strong wind on that side of the filter. The result for this section may therefore be of less value than would otherwise have been the case.

(2) Percolating filters constructed of medium-sized material (say, $\frac{1}{2}''$ in diameter), which temporarily retards the passage of suspended matter through the filter, while allowing free access of air to the interior.

(3) Percolating filters constructed of very fine material.

Percolating Filters Constructed of Medium-Sized Material.

142. In filters constructed of medium-sized material the suspended solids are arrested and held for some time in the upper layers of the material, and this part of the filter therefore receives a larger proportion of oxidizable suspended matter than the middle or lower parts. Where much suspended matter has to be dealt with, such filters tend to become choked in the uppermost few inches of the material, and to prevent the proper distribution of the liquid over the bed. In a filter of this kind, air is probably carried into the interior from the top downwards by the fall of the sewage liquor upon the material. There are many examples of filters of this class where the material is held in position by solid walls and where air could only gain access to the filter either through the outlet valves connecting to the drains or through the surface of the material. Colonel Harding and Mr. Harrison, at Leeds, showed clearly that after serious ponding took place on the surface of a filter of medium-sized material, although provided with perforated walls which would allow of side aeration, oxidized nitrogen almost entirely disappeared from the effluent, and the effluent then became putrescible. This experiment, however, does not conclusively show that aeration does not also take place through the sides of a filter with perforated walls, as the deterioration of the effluent might have been due to the unequal passage of the sewage liquor through the bed owing to impaired distribution, and so far as we are aware no experiments have been made which show conclusively how the interior of a percolating filter of medium-sized material is replenished with air.

On general grounds, we should think it better to arrange a given volume of medium-sized material in the form of a shallow rather than of a deep percolating filter. In this way better aeration would be maintained throughout the filter and the suspended solids in the liquor treated would be spread over a greater quantity of the filtering material.

Percolating Filters Constructed of Very Fine Material.

143. In filters constructed of very fine material, the material not only retains suspended matter on the surface, but also prevents the free access of air to the interior. When sewage liquor is applied to such a filter, almost the whole of the suspended matter is retained on the surface of the material, with the result that after a time the surface becomes completely choked. The filter has then either to be washed by upward flow, with simultaneous raking of the top few inches of the fine material, or it must be rested until the suspended matter on the surface is sufficiently dry to be raked off.

In the majority of cases, these filters are fed from a flushing tank, or the fine material itself is wholly relied upon for aiding uniform distribution. As showing that in the latter case (and presumably in the former also) a filter depends chiefly upon periods of rest for the access of air to the interior, we may quote the following experiment :—

At Prestolee, in Lancashire, there are three small filters which have a surface layer of very fine clinker : the material at the bottom of the filter is about one inch in diameter. The filters are entirely closed in at the sides, and at the bottom connect with the air through a single outlet valve only. The method of working the filters is simply to allow the septic tank liquor to flow on to the surface of one of them by means of half pipes, and then to percolate through to the outlet drains. The suspended matter in the tank liquor, being caught on the surface, soon chokes the fine material near the half pipes, and the liquor then gradually spreads over the whole surface of the filter. When the surface is about two-thirds or four-fifths ponded, the tank liquor is diverted to the second filter and the first is allowed to rest and dry off, after which the suspended matter is carefully removed with a spade.

144. In order to gain some idea as to how long it would be possible to work one of these filters without resting, the following experiments were made :—

On Wednesday, January 4th, 1905, at 2.30 p.m., septic tank liquor was turned on to Bed No. 1, which had previously been rested for $29\frac{1}{2}$ hours, *i.e.*, a shorter period of

rest than the usual two days. The first samples of effluent from the bed were drawn thirty minutes after the start, at which time the effluent had begun to flow out at a fair rate, and others were taken out from time to time, as shown in the table below. The experiment lasted until January 9th, at 4.20 p.m., *i.e.*, for fully five days, the weather for the greater part of this time being showery, but the flow of sewage never much above the normal.

During the course of the experiment, four samples of septic tank liquor were drawn, viz :—

On January 4th at 2.30 p.m.
On January 5th at 10.45 a.m.
On January 6th at 9.45 a.m.
On January 9th at 4.0 p.m.

These samples were very much alike in composition, and the figures of analysis are therefore averaged in the table, and placed in one column. Incidentally they show that the liquor is very weak, but this is quite normal for Prestolee.

	Average of 4 Septic Tank Liquors.	Effluents.					
Drawn		Jan. 4th., 30 minutes after starting filter.	Jan. 4th., 6½ hours after starting filter, the surface of which was then three quarters ponded.	Jan. 5th., 20¾ hours after starting filter, the surface of which was then four-fifths ponded.	Jan. 5th., 27½ hours after starting. Surface almost completely ponded	Jan. 6th., 43¾ hours after starting. Surface nine-tenths ponded.	Jan. 9th., 121½ hrs. after starting. Filter surface then completely ponded.
Analysed :		Jan. 5th.	Jan. 6th.	Jan. 6th.	Jan. 9th.	Jan. 9th.	Jan. 10th.
Parts per 100,000.							
Ammoniacal Nitrogen	0·75 (4) *	0·04	0·19	0·28	0·26	0·32	0·60
Albuminoid Nitrogen	0·22 (4)	0·07	0·06	0·05	0·07	0·07	0·07
Oxidized Nitrogen	—	0·90	0·44	0·40	0·32	0·27	0·00
"Oxygen absorbed" *at once* at 27°C	0·76 (4)	0·14	0·23	0·17	0·29	0·35	0·31
"Oxygen absorbed" *in 4 hours*	3·21 (4)	0·56	0·91	0·47	0·77	0·81	0·65
Dissolved oxygen taken up in 24 hours at 18°C	1·20 (1)	0·48	0·62	0·85	0·56	0·66	0·55
Incubator test (Scudder)	—	Passed.	Passed.	Passed.	Passed.	Passed.	Failed.
„ „ (by smell)	—	Passed.	Passed.	Passed.	Passed.	Passed.	Failed.
Smell when drawn	—	Faint soapy.	Good.	Good.	Good.	Good.	Strong sewage.
Smell when analysed	—	Slight soapy and earthy.	Slight soapy.	Good.	Slight soapy and earthy.	Good.	Slightly unpleasant.
Chlorine	2·93 (4)	—	—	—	—	—	—
Solids in suspension	6·42 (2)	—	—	—	—	—	—
Solids by centrifuge (vols.)	17·4 (3)	0·0	0·0	0·0	0·0	0·0	0·0
Oxygen in solution (when analysed) *c.c. per litre* †	—	5·6	4·2	5·1	0·0	1·0	0·7

* The figures in brackets indicate the number of estimations in each case.

† In comparing the figures for dissolved oxygen found on the day of analysis, it is important to note that these estimations were made at different intervals of time after the samples were drawn. Those which could not be examined at once were kept in ice, but the second sample of January 5th was at atmospheric temperature for two days after being drawn; this no doubt accounts for its oxygen being exhausted.

At 6½ hours after the start, the bed had become ponded over three-fourths of its surface and the ponding gradually increased, but with fluctuations, until the bed was completely under water.

Concurrently with this, the figures for ammoniacal nitrogen and for nitric nitrogen (no nitrite being present in any sample on the day of analysis) show that the oxidation gradually decreased as the experiment proceeded. The figures both for "oxygen absorbed" from permanganate and for dissolved oxygen absorption are less regular, but this is no doubt partly due to the fact that all the effluents could not be examined at equal intervals of time after they were drawn. After five days the effluent even from this very weak tank liquor became putrescible.

145. It is clear, therefore, that percolating filters of very fine material can only be worked for a certain limited time without being rested, and, in order to obtain the maximum amount of work out of a given quantity of fine material, it would seem better to arrange it in the form of a shallow rather than in the form of a deep filter, provided the distribution is efficient.

Depth of Fine Percolating Filters.

Reid, 27075–27164.

146. The question of the most suitable depth for fine filters was specially brought to our notice by Dr. George Reid, the Medical Officer of Health for the County of Staffordshire.

In connection with his investigation of the fine grain filters at Hanley, Dr. Reid collected samples at the following depths from the surface of the filters, viz. :—1 foot, 2 feet, 3 feet, and (the bottom) 4 feet 6 inches.

The analyses of these samples, and also of the septic tank liquor, the detritus tank liquor, and the original sewage, are given in the following table :—

Parts per 100,000.

———	Sewage.	Detritus Tank.	Septic Tank.	Filter 1 foot	Filter 2 feet	Filter 3 feet	Filter 4·5 feet
No. of Records	18	13	16	16	16	16	16
Total Solids	170·9	118·1	107.8	101·5	101·1	101·8	103·5
Solids in Suspension	63·5	17·0	7·6	0·25	0·09	0·14	—
Solids in Suspension (Organic)	28·5	6·8	3.8	0·16	0·05	0·06	—
Solids in Suspension (Mineral)	34·9	10·1	3·8	0·08	0·03	0·08	—
Chlorine	11·0	10·0	9·9	9·4	9·5	9·4	9·5
Free Ammonia	2·154	1·643	1·716	0·036	0·020	0·009	0·043
Albuminoid Ammonia	0·972	0·486	0·340	0·052	0·037	0·031	0·027
*Oxygen absorbed in 4 hours at 80°F.	5·019	2·726	2·184	0·328	0·286	0·244	0·259
*Oxygen absorbed in 3 minutes before incubation	1·862	0·975	0·836	0·093	0·077	0·060	0·070
Oxygen absorbed in 3 minutes after incubation (3 days)	2·176	1·095	1·571	0·0677	0·060	0·052	0·039
Nitric Nitrogen on day of collection	0·02	0·02	Nil	1·64	1·82	1.75	1·70
Nitric Nitrogen day after collection	0·10	0·09	0·09	2·07	1·99	1·85	1·99
Nitrous Nitrogen on day of collection	0·029	0·014	Nil	0·003	0·011	0·005	0·005
Nitrous Nitrogen day after collection	0·029	0·022	Nil	0·003	0·007	0·008	0·002
Column necessary to obscure test lines (inches)	0·5	1·6	1·5	Over 24	Over 24	Over 24	Over 24

From these experiments Dr. Reid had drawn the inference that, in the case of the Hanley sewage "the lower two or three feet of filter medium is absolutely unnecessary, and so far as the cost of construction of the filters is concerned, the expenditure might be reduced by about one half."

* From weak permanganate.

He also suggested that a much better result would be obtained from a given quantity of *fine* filtering material if it were arranged in the form of a shallow filter, than if it were arranged in the form of a filter 6 feet deep; and, further, that to estimate the amount of filter required for a given flow of sewage, in cubic yards, without reference to the depth of the filter, was open to objection, inasmuch as the lower layers of a fine filter were less efficient than the top one or two feet. Reid, 27145.

The points raised by Dr. Reid are of considerable importance, and we considered it desirable to make further experimental investigations in regard to them, especially as the results obtained at Hanley in respect of fine filters differed so materially from the results which we had obtained elsewhere with coarse filters.

Dorking experiments as to depth of filters.

147. Our experiments were carried out at Dorking, under the charge of Mr. E. H. Richards, our resident chemist. For the purpose of the experiments, we constructed two filters 4 feet 10 inches deep, one filled with fine material and the other with coarse material, and two filters 2 feet 5 inches deep, one filled with fine material and the other with coarse material.

For convenience the two deep filters were constructed in the form of one circular filter with a dividing partition between the coarse and fine material. The shallow filters were also constructed in a similar manner. The distribution was by means of revolving sprinklers, fed intermittently from small tipping troughs. At the suggestion of Dr. Reid, who very kindly gave every possible help in the planning of the experiment, the distribution was carefully tested before the experiment started and was found to be as perfect as could reasonably be expected. The flush of tank liquor (5 gallons) on to the filters took place as follows :—

During Experiment I. - - once every 7 minutes.

During Experiment II. - - once every $3\frac{1}{2}$ minutes.

The following table gives particulars of the four filters :—

Dorking Experimental Filters.

——	Material.	Depth of Material.	Size of Material.	Contents of filter.
				Cube yards.
Coarse Shallow Filter - -	Clinker.	2′ 5″	1″ to 4″ throughout.	5·14
Coarse Deep Filter - - -	Clinker.	4′ 10″	1″ to 4″ throughout.	10·28
Fine Shallow Filter - -	Clinker.	2′ 5″	Top 1′ $2\frac{1}{2}$″ of $\frac{1}{8}$″ to $\frac{1}{4}$″ diam. Bottom 1′ $2\frac{1}{2}$″ of $\frac{1}{4}$″ to $\frac{1}{2}$″ diam.	5·14
Fine Deep Filter - - -	Clinker.	4′ 10″	Top 2′ 5″ of $\frac{1}{8}$″ to $\frac{1}{4}$″ diam. Bottom 2′ 5″ of $\frac{1}{4}$″ to $\frac{1}{2}$″ diam.	10·28

The sewage treated in the experiments was drawn, by means of a bypass, from the Dorking outfall at a constant flow. It may be described as almost entirely domestic sewage of about average strength.

Table I. shows the figures of analysis given by 21 sets of average samples of the sewage taken from November, 1905, to November, 1906.

TABLE I.

Figures for Screened Sewage.

24-hours samples.

Parts per 100,000.	Average.	No. of estimations.
Ammoniacal Nitrogen (2·63 to 5·69)	4·65	21
Albuminoid Nitrogen (0·56 to 1·66)	1·00	20
Total Organic Nitrogen (1 17 to 3 11)	1·92	20
Oxidized Nitrogen (0·00 to 0 76)	0·11	21
Total Nitrogen (4·51 to 5·88)	6·72	20
Oxygen absorbed at once at 27°C. (1·20 to 3·41)	2·38	21
Oxygen absorbed in 4 hours (6 37 to 14·77)	10·01	21
Solids in suspension (11·7 to 32·8)	21·50	21
Calculated strength* 96	—	—

* Strength expressed in terms of the number of parts by weight of oxygen required to oxidize 100,000 parts of sewage, arrived at on the basis of the formulæ suggested by Dr. McGowan—*see* p. 16 of this Report, and Dr. McGowan's Memorandum in Appendix IV.

The sewage, before filtration, was precipitated with ten grains of alumino-ferric and five grains of lime per gallon, and was then allowed to pass through a tank of sufficient capacity to give ten hours continuous flow settlement. The tank was cleaned once a week, as a rule, but twice a week in hot weather.

Experiment I. (*June* 17*th*, 1907, *to October* 17*th*, 1907.)

148. On June 17th, 1907, the four filters were started working at the rate of seventy-five gallons per *square yard* per day for each filter. This was equivalent to a rate of ninety-three gallons per cube yard for each shallow filter and 46·5 gallons for each deep filter. This small dose was intentional, the idea being to work the filters with gradually increasing volumes of liquor and to note the order in which the effluents deteriorated in quality. The above rate of working continued without cessation until October 17th, 1907. The surface material of the coarse filters was soon covered with a green growth as is usual at Dorking at that time of the year. The growth was thin and had no apparent effect upon the aeration of the filters or upon the passage of the tank liquor through the material.

The material in the two fine filters was comparatively free from growth, and at no time during this experiment did any ponding of the surface occur. The upper layers of the fine material swarmed with small red worms.

During the four months all the effluents and the precipitation liquor were examined by sets of average samples drawn hourly for eight hours every eight days.

The figures given in Table II. are therefore representative of the working of the filters under all conditions.

TABLE II.

Deep and Shallow Filter experiment.

Average Figures of Analysis for Precipitation Liquor and Effluents.

All Filters working at the rate of 75 gallons per square yard.

Twelve Analyses.

June 27th to September 27th, 1907.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved oxygen taken up in 48 hours at 18° C.	Dissolved oxygen taken up in 5 days at 18° C.	Incubator test (Smell).	Solids in Suspension.	Centrifuge (Volumes).	Chlorine.	Rate of Filtration in Galls. per cube yard.
Precipitation liquor - - -	4·94	0·51	0·02	0·08	1·72	5·44	—	—	—	5·73, 3·53 (vol.) 2·20 (non-vol.)	60	—	—
Coarse shallow filter effluent - -	0·66	0·11	0·14	3·14	0·47	1·35 1·12 (paper filtered)	0·57	1·47 0·48 (paper filtered)	12+	1·53, 0·99 (vol.) 0·54 (non-vol.)	27	—	93
Coarse deep filter effluent - -	0·14	0·08	0·05	4·03	0·31	0·91 0·76 (paper filtered)	0·24	0·67 0·32 (paper filtered)	12+	1·28, 0·77 (vol.) 0·51 (non-vol.)	26	—	46·5
Fine shallow filter effluent - -	0·08	0·04	0·04	4·00	0·27	0·57	0·04	0·12	12+	—	None	—	93
Fine deep filter effluent - - -	0·03	0·04	Trace.	4·26	0·16	0·51	0·03	0·15	12+	—	Trace	—	46·5

The sign + means that the sample did not putrefy on incubation.

The precipitation liquor treated was fairly strong. It had a calculated strength * of about sixty-one.

The effluents from the two coarse filters were both very good, but the *liquid* portion of effluent from the deep filter contained only about two-thirds as much oxidizable matter as that from the shallow filter, as judged by the oxygen absorbed test. The difference is shewn by the following figures :—

	Effluent from the coarse shallow filter.	Effluent from the coarse deep filter.
Ammoniacal nitrogen	0·66	0·14
Nitric nitrogen	3·14	4·03
Oxygen absorbed in 4 hours by paper-filtered effluent	1·12	0·76
Dissolved oxygen taken up in 5 days by paper-filtered effluent	0·48	0·32

The effluents from the two fine filters were, for practical purposes, alike, the oxidation having been carried very far in each case, as is shown by the following figures :—

	Effluent from fine shallow filter.	Effluent from fine deep filter.
Ammoniacal nitrogen	0·08	0·03
Nitric nitrogen	4·00	4·26
Oxygen absorbed from permanganate in 4 hours	0·57	0·51
Dissolved oxygen taken up in five days	0·12	0·15

All four effluents may be classed as good to very good, and all the filters were sufficiently, or more than sufficiently, deep, for the volume and the strength of the liquid treated.

The results from the deep and shallow fine filters are in agreement with those obtained by Dr. Reid at Hanley. They show that, *with the amount of sewage liquor being treated*, the extra depth in the deep filter was not required ; or, in other words, that passage through the first half of the deep filter was sufficient to oxidize almost the whole of the oxidizable matter in the liquor put on the filter.

Salt Experiment I.

149. At the conclusion of this first experiment an attempt was made, as at Ilford, to find the approximate average time taken by the precipitation liquor to pass through each filter.

About 28 lbs. of common salt were dissolved in water, and half the solution was poured into the tipping-trough supplying each pair of filters, in such a way as to interfere as little as possible with the natural working of the distributors.

Approximately 7 lbs of salt were thus flushed on to each filter.

Samples of the four effluents were taken first at one minute intervals, and subsequently at longer intervals over a period of 56 hours, until the salt had apparently all passed through the filters.

The chlorine in these samples plotted against time of drawing is shewn in Diagram 2.

These curves suggest the conclusion that a sample of effluent drawn at a given time is composed of a mixture of liquid which has been in contact with the filtering material for times varying (in all four cases) from about thirty minutes or less, to something like sixty *hours* or more.

The proportion of liquid which has been in contact with the filtering material for a short time to the proportion of liquid which has been in contact for a long time would largely depend upon the depth of the filter, and upon the nature and size of the material of which the filter is composed.

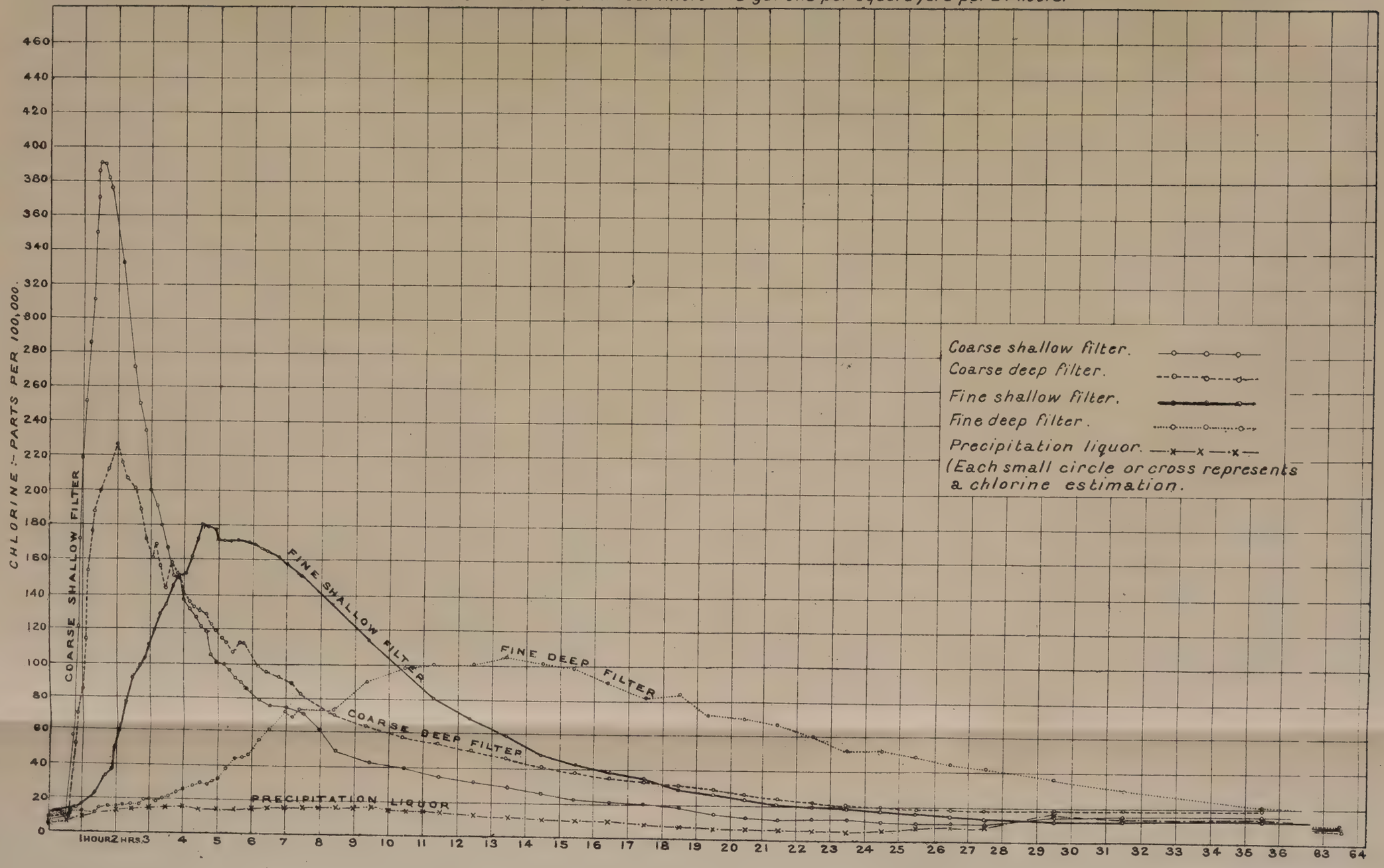
* *See* section of this Report on Strength of Sewage, p. 15.

CURVES SHEWING THE RATES OF FILTRATION THROUGH THE TWO COARSE AND THE TWO FINE FILTERS AT DORKING, AS TESTED QUANTITIVELY WITH A SOLUTION OF SALT.

OCTOBER 9TH 1907.

Rate of filtration on all four filters = 75 gallons per square yard per 24 hours.

DIAGRAM 2.



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To draw any exact conclusions as to the average time of contact in each of the four filters appears to be almost impossible. We may, however, give the following ratios, etc :—

—	Total quantity of salt washed out of filter in 30 hours.		Time taken for half the average quantity of salt to wash out.		Hour line upon which the centre of gravity of the curve figure falls.		Total area enclosed by the curve figure.	
	Weight in lbs.	Proportion to 7 lbs	Hours.	Time ratio.	Hours	Hour line ratio.	Cubic inches.	Area ratio.
Coarse shallow filter - -	4·36	0·62	3·0	1·0	5·33	1·00	12·9	1.00
Coarse deep filter - -	4·59	0·65	5·5	1·8	9·0	1·63	13·0	1·01
Fine shallow filter - -	4·98	0·71	7·0	2·3	9·0	1·63	14·0	1·08
Fine deep filter - -	5·42 (39 hrs.)	0·77	14·5	4.8	17·0	3·10	14·0	1·08
Average - - - -	4·83	—	—	—	—	Average.	13·5	—

As judged by the time taken for half the average weight $\left(\frac{4{\cdot}83}{2}\text{lbs.}\right)$ of salt to issue in the effluent, the time of contact in the coarse deep filter was nearly double that given in the coarse shallow filter, and rather less than the time of contact given in the fine shallow filter. In the fine deep filter it was almost exactly double the time given in the fine shallow filter.

Upon this basis of calculation, the fine deep filter ought to give the best effluent, the fine shallow filter the next, the coarse deep filter the next, and the coarse shallow the worst. The quantities of oxidizable matter treated were not sufficient to give any true idea of the relative oxidizing power of each filter, but it will be seen that the figures of analysis do arrange the effluents in this order.

Experiment II. (*October 18th*, 1907, *to January 12th*, 1908.)

150. On October 18th, 1907, the rate of working was increased to 150 gallons per *square yard* per day for each filter. This was equivalent to a rate of 186 gallons per cube yard for each of the two shallow filters and 93 gallons for each of the two deep filters. This rate of working continued until December 22nd, when all the filters were given a week's rest in cold dry weather. On December 29th they were started again at the same rate, and from this time they worked without cessation until January 28th, when the experiment stopped.

The increased rate of working and the low atmospheric temperature showed their effects on the nitrification, the ammonia rising and the nitrate falling in all the effluents. Moreover, a grey growth (*Cladothrix dichotoma*, Cohn) made its appearance and began to flourish on the surface of the two coarse filters towards the end of October, gradually increasing in thickness during the two following months.

The same growth appeared on the surface of the two fine filters ; this also increased, but never to anything like the same extent as on the coarse filters. On November 20th local ponding began on both fine filters, being rather worse on the shallow filter than on the deep. On December 2nd both the fine filters were raked over for the first time, and as this was done afterwards whenever necessary, neither the growth nor the suspended matter caught in the top few inches of the fine clinker had very much effect upon the working of these filters. There is no doubt that the effect of the growth was much more marked in the case of the two coarse filters.

The severe frosts in January killed off the growths on the fine filters, and to a certain extent on the coarse filters also, but with the return of the milder weather the growth re-asserted itself. Although the filters were at times completely frozen over between the jets of the sprinklers, none of the effluents deteriorated seriously. The coarse deep filter suffered most in this way from its exposed position.

The averages of the figures of analysis are given in Table III.

They were obtained from samples drawn in an exactly similar way to those in Experiment I.

TABLE III.

Deep and Shallow Filter Experiment.

Average Figures of Analysis for Precipitation Liquor and Effluents.

All Filters working at the rate of 150 gallons per square yard.

Ten Analyses.

October 22nd, 1907, to January 12th, 1908.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18° C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator test (smell)	Solids in Suspension.	Centrifuge (volumes).	Chlorine.	Rate of filtration in gallons per cube yard per day.
Precipitation Liquor - - -	4·13	0·50	0·09	0·19	1·44	4·85	—	—	—	5·70, 3·03 (vol.) 2·67 (non-vol.)	64	7·48	—
Coarse shallow filter effluent - -	0·99	0·16	0·08	2·23	0·41	1·26 0·87 (paper filtered)	1·00	2·42 0·52 (paper filtered)	10+	2·65, 1·75 (vol.) 0·85 (non-vol.)	53	7·05	186
Coarse deep filter effluent - -	0·55	0·10	0·07	2·69	0·27	0·94 0·79 (paper filtered)	0·51	1·40 0·42 (paper filtered)	10+	1·51, 1·09 (vol.) 0·42 (non-vol.)	34	7·07	93
Fine shallow filter effluent - -	0·86	0·11	0 05	2·80	0·34	0·90	0·46	1·03	10+	1·00 (approx.)	26	7·02	186
Fine deep filter effluent - - -	0·35	0·06	0 03	3·25	0·24	0·60	0·21	0·42	10+	0·25 (approx.)	5	7·02	93

In this second experiment, the precipitation liquor treated was distinctly weaker than it was in the first experiment. Its calculated strength was only fifty-four as against sixty-one. This was no doubt owing to the heavy rainfall in the last months of the year.

Comparing the effluents from the the two coarse filters, we have the following figures :—

	Effluent from the coarse shallow filter.	Effluent from the coarse deep filter.
Ammoniacal Nitrogen	0·99	0·55
Nitric Nitrogen	2·23	2·69
Oxygen absorbed in 4 hours by paper-filtered effluent	0·87	0·79
Dissolved Oxygen taken up by paper-filtered effluent in 5 days	0·52	0·42

It would have been expected that with the greater flow per cube yard the difference between the effluents from the two coarse filters would have become accentuated, but in actual fact it is, if anything, rather less than it was in Experiment I, though at the same time neither effluent was of quite such good quality. The explanation of this result is, we think, to be found in the development of growths upon the surface of the coarse material and some way down into it which took place during the experiment. This undoubtedly interfered with the normal working and, as will be shown later, altered the times of contact given. With regard to the effluents from the fine filters (which, it will be remembered, were in the first experiment practically identical), these showed a greater difference than before as is evident from the following figures :—

	Effluent from fine shallow filter.	Effluent from fine deep filter.
Ammoniacal Nitrogen	0·86	0·35
Nitric Nitrogen	2·80	3·25
Oxygen absorbed in 4 hours by paper-filtered effluent	0·90	0·60
Dissolved Oxygen taken up in 5 days	1·08	0·42

Some growth occurred on the fine filters, but it had much less effect upon the working of them than the growth had upon the working of the coarse filters, mainly because of the surface raking adopted.

So far as the coarse filters in Experiment II are concerned, the value of the comparison of the results was vitiated by the growth.

As regards the fine filter effluents, while both are good, that from the deep filter contained only about half the residual oxidizable matter as that from the shallow filter.

At the same time, the total amount of matter which was oxidized by the fine filter, 4 feet 10 inches deep, was little more than the total amount which was oxidized by the fine filter of half the depth.

As in Experiment I., all the filters continued sufficiently (or more than sufficiently) deep for the volume and strength of the liquor treated.

Salt Experiment 2.

151. At the conclusion of Experiment II another salt test was made in order to compare the curves obtained at this rate of flow (150 gallons per square yard) with those in Experiment I when the rate was 75 gallons per square yard.

The result is shewn in Diagram 3. Exactly the same amount of salt was used as before, viz. 7lbs. for each of the four filters, but as the flow of liquid was now doubled, the chlorine figures are correspondingly lower in each case.

Interpreting the curves in the same way as those of Diagram 2, we obtain the following figures :—

	Total quantity of salt washed out of filter in 23 hours.		Time taken for half the average quantity of salt to wash out.		Hour line upon which the centre of gravity of the curve figure falls.		Total area enclosed by the curve figure.	
	Weight in lbs.	Proportion to 7 lbs.	Hours.	Time ratio.	Hours.	Hour line ratio.	Cubic inches.	Area ratio.
Coarse shallow filter - - -	4·2	0·60	2·27	1·00	3·8	1·00	6·98	1·00
Coarse deep filter - -	4·87	0·69	3·00	1·32	5·6	1·48	7·96	1·14
Fine shallow filter - -	4·17	0·60	3·70	1·63	5·8	1·53	6·28	0·90
Fine deep filter - - -	4·36	0·62	6·30	2·77	9·4	2·48	6·98	1·00
Average - - - - -	4·40	—	—	—	—	Average.	7·05	—

It will now be seen that in the two coarse filters, especially in the shallow one, the time taken for half the average quantity of salt to wash out was distinctly more than half what it was in Experiment I.

The effect of this is to bring the ratio figures for average time of contact in the two coarse filters much nearer together, viz., 1·0 : 1·32 as against 1·0 : 1·8 in Experiment I.

The same thing is seen but to a lesser extent with the fine filters, where the ratio figures are 1·63 : 2·77 as against 2·3 : 4·8.

The figures of analysis run parallel with this, there being less difference between the two coarse filter effluents than in Experiment I. Further, the rate of filtration is now sufficient to bring about a difference in the figures of analysis for the fine filter effluents.

Salt Experiment 3.

152. The appearance of the filters at this time led us to surmise that the difference between the ratio figures of Salt Experiment 1 and those of Salt Experiment 2 was to be ascribed to the development of *Cladothrix dichotoma* on the filtering material, especially on the coarse material.

In order to satisfy ourselves as to this, we cut down the flow on to the filters to the original rate of 75 gallons per square yard *immediately* after the conclusion of Salt Experiment 2, and proceeded to make a third Salt Experiment. Apart, therefore, from the difference in the state of the filters, the conditions of this Experiment were precisely the same as in Salt Experiment I.

DIAGRAM 3.

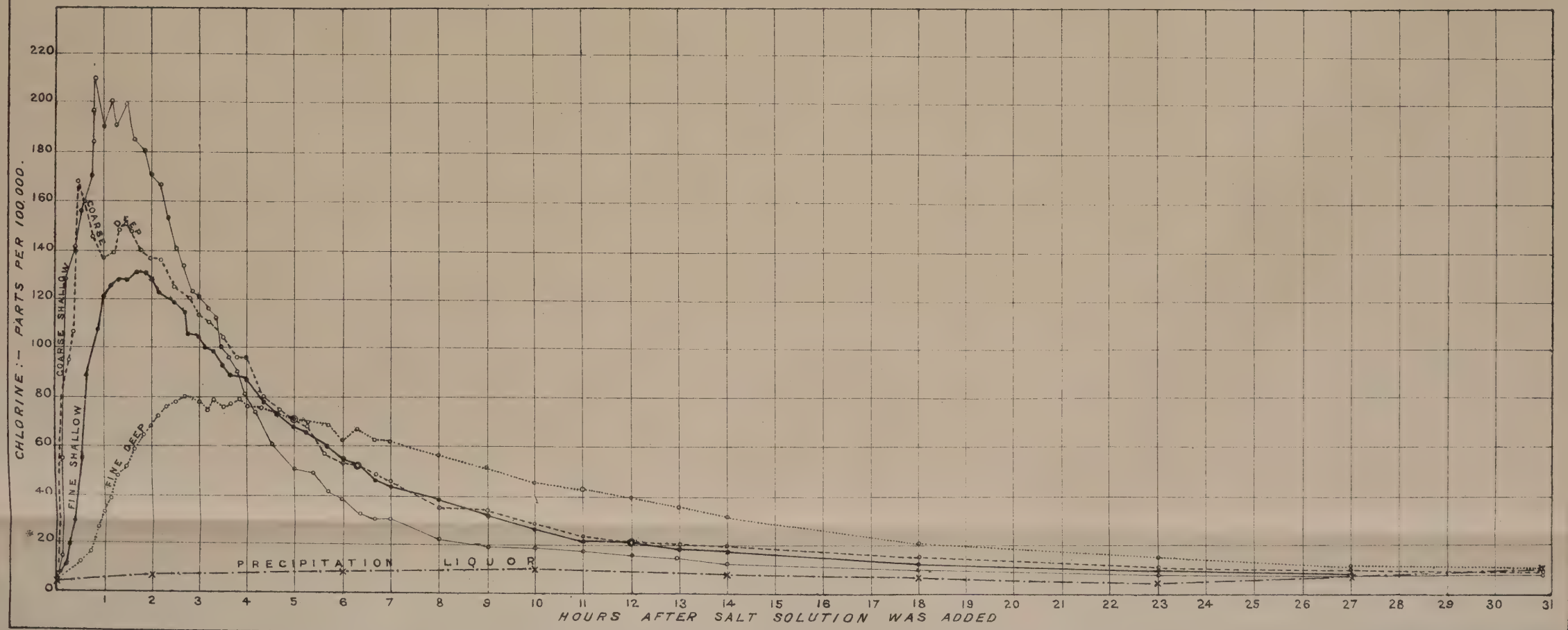
CURVES SHOWING THE RATES OF FILTRATION THROUGH THE TWO DEEP AND THE TWO SHALLOW FILTERS AT DORKING, AS TESTED QUANTITIVELY WITH A SOLUTION OF SALT.

Rate of filtration on all four filters = 150 gallons per square yard per 24 hours.

Coarse shallow filter.
Coarse deep filter.
Fine shallow filter.
Fine deep filter.
Precipitation liquor.

JANUARY 23RD 1908.

(Each small circle or cross represents a chlorine estimation)



5236. 08

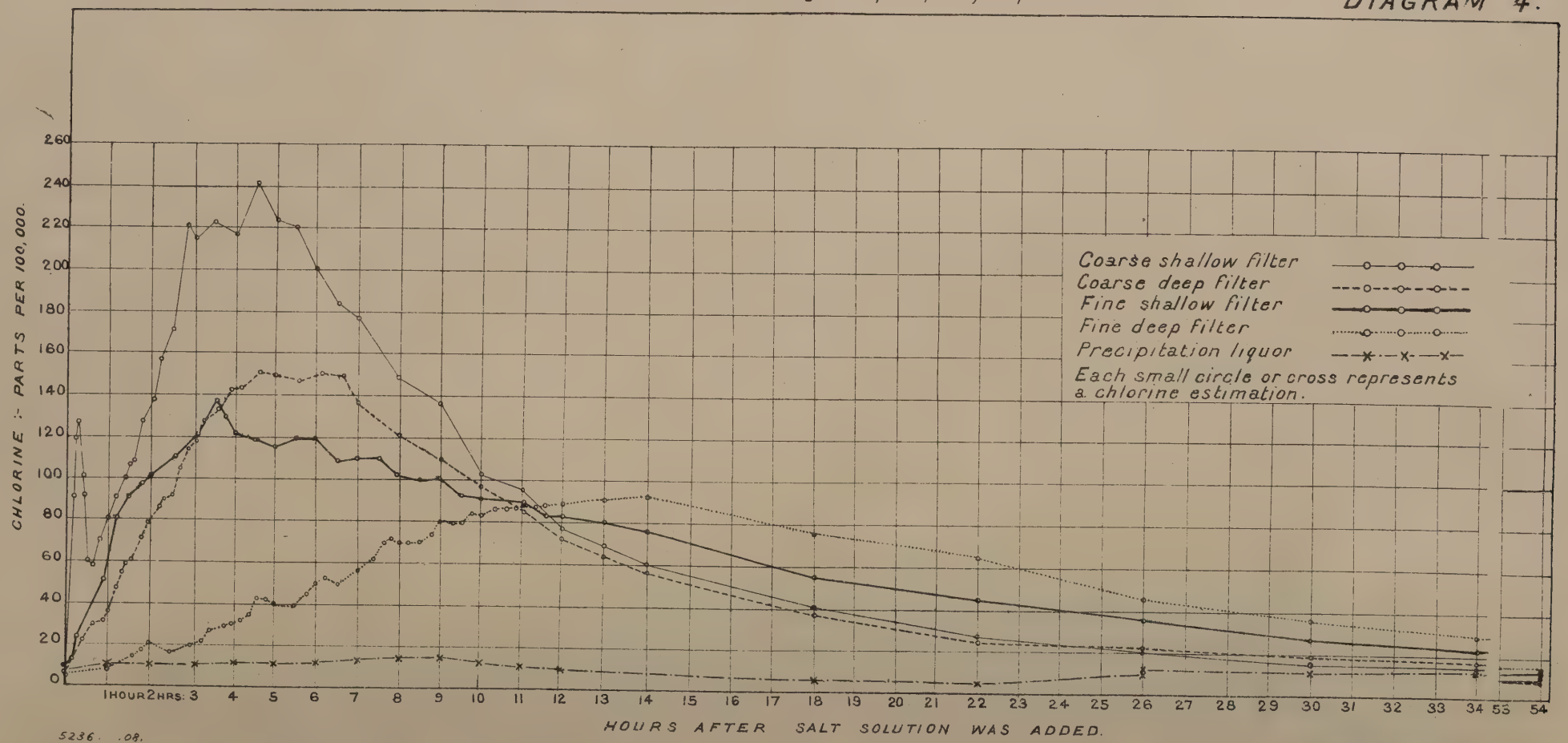
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CURVES SHEWING THE RATES OF FILTRATION THROUGH THE TWO COARSE AND THE TWO FINE FILTERS AT DORKING, AS TESTED QUANTITIVELY WITH A SOLUTION OF SALT.

FEBRUARY 6TH 1908

Rate of filtration on all four filters = 75 gallons per square yard per 24 hours.

DIAGRAM 4.



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The result of Salt Experiment 3 is shewn on Diagram 4.

Again interpreting the curves as before we obtain the following figures :—

	Total quantity of salt washed out of filter in 46 hours.		Time taken for half the average quantity of salt to wash out.		Hour line upon which the centre of gravity of the curve figure falls.		Total area enclosed by the curve figure.	
	Weight in lbs.	Proportion to 7 lbs.	Hours.	Time ratio.	Hours.	Hour line ratio.	Cubic inches.	Area ratio.
Coarse shallow filter - -	6·97	0·99	6·3	1·00	8·8	1·00	22·26	1·00
Coarse deep filter - -	6·02	0·86	9·1	1·44	11·0	1·25	15·80	0·70
Fine shallow filter - -	6·87	0·98	10·2	1·62	13·9	1·58	18·20	0·82
Fine deep filter - - -	6·29	0·90	16·9	2·68	19·6	2·22	16·28	0·73
Average - -	6·54	—	—	—	—	—	18·13	—

The ratio figures for the time taken for half the average quantity of salt to wash out in this experiment were thus practically the same as in Salt Experiment 2, viz., 1·0: 1·32 and 1·0 : 1·44 for the two coarse filters and 1·63 : 2·77 and 1·62 : 2·68 for the two fine filters.

In other words, given a filter in the same state, the time of contact is inversely proportional to the rate of flow.

While, therefore, the growth interfered with the progress of the experiment as originally outlined, it has helped in a striking way to shew how close is the relationship between the time of contact and the quality of the effluent.

General Conclusions as to Depth of Percolating Filters.

153. Our Dorking experiments are not completed, and some points are not yet settled, but we think that the results obtained by other workers, together with those arrived at by us, bring out the following points fairly clearly :—

(1) That the deeper the filter the better the effluent. This holds both for fine and coarse material, assuming good distribution and aeration.

(2) For practical purposes and assuming good distribution, the same purification will be obtained from a given quantity of *coarse* material, whether it is arranged in the form of a deep or of a shallow percolating filter, if the volume of sewage liquor treated per cube yard be the same in each case.

Thus, a filter, 3 feet deep, worked at the rate of x gallons per square yard per day, would give similar results to a filter 6 feet deep, worked at the rate of 2 x gallons per square yard.

In the absence of clogging, the balance would be slightly in favour of the deep filter, because the greater the depth the more the errors of distribution would be neutralised. There must always be a limit of shallowness (say 3 feet), beyond which it would be unwise to go, for however good the distribution might be, if a coarse filter were constructed very shallow, a considerable proportion of the sewage would pass through by "short cuts."

(3) With regard to filters of *fine* material, if the liquid to be purified were absolutely free from suspended and colloidal solids, and if thorough aeration could be maintained, the statement just made for filters of coarse material might possibly hold good for filters of fine material also. In practice, however, these conditions can scarcely be maintained with large rates of flow, and we think that the greatest efficiency can be got out of a given quantity of *fine* material by arranging it in the form of a shallow filter rather than of a deep filter. But we are not in a position to make an exact quantitative statement as to the difference in efficiency of the two forms.

It is probable that for the treatment of a strong sewage liquor, the filter should not be quite so shallow as for a weak liquor, but the point has not been fully worked out.

(4) The extent of the purification effected by a percolating filter varies with the average length of time taken by the sewage liquor to pass through the filtering material, assuming that proper aeration of the filter is maintained.

Fowler, 22819.

Size of Material.

154. The size of the filtering material should depend, very largely, upon the amount and character of the suspended matter in the liquid to be filtered. Fine or medium-sized material undoubtedly produces the best effluents, so long as it is kept free from water-logging ; but, unless the rate of filtration is slow, such filters soon clog if much suspended matter is contained in the liquid which is being filtered.

At Leeds, screened crude sewage, containing about 50 parts of suspended matter per 100,000, was treated upon filters of coarse material (over 4 inches in diameter) for at least eight or nine months ; but it was found that when the same sewage was treated on a Ducat filter constructed of fine to medium clinker ($\frac{3}{8}$-inch to $\frac{5}{8}$-inch diameter), even at a slower rate, the filter became clogged in a month. The rates of filtration were as follows :—

Through the coarse filter ($11\frac{1}{2}$ feet deep)	-	52 gallons per cube yard per day.
Through the fine filter (10 feet deep)	-	45 gallons per cube yard per day.

In considering the question of size of filtering material, the character of the suspended matters in the sewage to be treated must also be taken into account.

No doubt the amount of fibre in the sewage was the chief cause of the very rapid choking of the fine Ducat filter at the Leeds works. As we have already mentioned, this filter became clogged within a month when screened sewage was put upon it, and with septic tank liquor, containing about 18 parts of suspended matter per 100,000, it completely choked after about two and a half years. The rate of filtration during the experiment with septic tank liquor was about 57 gallons per cube yard per day.

155. The following tables give particulars as to the size of filtering material in use at a number of places which we have had under observation.

Place.	Nature of Material.	Size of Material.	Depth of Material.	Amount of suspended matter in liquor treated. Parts per 100,000.		Calculated strength of liquor treated.	Method of Distribution.	Whether delivery of liquid is Continuous or Intermittent.	Rate of filtration in gallons.		Condition of Filters.	Remarks.
				Hourly samples in dry weather.	Average of chance Samples.				Per square yard per 24 hours.	Per cube yard per 24 hours.		
Treatment of Crude Sewage.												
Hendon - -	Clinker.	½ in. to ¾ in.	8 ft.	20	—	107	Tipping troughs.	Continuous.	125	40	Good after eight years.	Experimental Ducat filter. Fixed quantity treated daily.
Leeds - -	Clinker.	⅜ in. to ⅝ in.	10 ft.	—	85	173	Tipping troughs.	Continuous.	83	25	Clogged after one month.	Experimental Ducat filter. Fixed quantity treated daily.
Leeds - -	Clinker.	Over 4 ins.	11·5 ft.	—	53	123	Sprinkler.	Intermittent.	200	52	Choked with growth after 21 months.	Experimental Leeds filter. Fixed quantity treated daily.
Treatment of Settled Sewage.												
Clifton - -	Sand and cinders.	Very fine to coarse.	4 ft.	24	—	123	By fine material on surface.	Intermittent.	20·8	15·6	Good after fourteen years. Filters scraped every three months.	Six times the dry weather flow dealt with in storm times.
Dorking - -	Clinker.	2 ins. to 4 ins.	5 ft. 7 in.	—	9·4	80	Sprinkler.	Continuous.	223	120	Good after two years.	Experimental process. Fixed quantity treated daily.
Leeds - -	Clinker.	Over 1½ ins.	9 ft. 6 in.	—	12	69	Sprinkler.	Continuous.	200	63	Unchanged after one year.	Experimental process. Fixed quantity treated daily.
Little Drayton -	Granite.	⅜ in. to ¾ in.	7 ft. 6 in.	20	—	165	Tipping troughs.	Continuous.	48	19·5	Upper part of material requires washing after three or four years.	
Treatment of Septic Tank Liquor.												
Accrington -	Coke or clinker.	2 ins. to 4 ins.	9 ft. 3 in. to 7 ft.	—	—	92	Sprinkler.	Continuous.	425	140	Good after four to eight years.	Twice the dry weather flow dealt with.
Birmingham -	Broken brick, granite or slag	Medium to coarse.	—	—	7·3	159	Nozzles.	Continuous.	165	82	Good after three or four years.	
Caterham -	Coke.	⅜ in. to 3 ins.	5 ft.	12·6	—	161	Perforated pipes.	Intermittent.	51	30·7	Good after ten years.	Fixed quantity treated daily.
Dorking - -	Clinker.	2 ins. to 4 ins.	5 ft. 7 in.	—	9·5	82	Sprinkler.	Continuous.	223	120	Good after two years.	Experimental process. Fixed quantity treated daily.
Guildford -	Coke.	Over 2 ins.	6 ft.	16	—	125	Sprinkler.	Intermittent.	102	51	Good after nine months.	Experimental process. Fixed quantity treated daily.

Place.	Nature of Material.	Size of Material.	Depth of Material.	Amount of suspended matter in liquor treated. Parts per 100,000.		Calculated strength of liquor treated.	Method of Distribution.	Whether delivery of liquid is Continuous or Intermittent.	Rate of filtration in gallons.		Condition of Filters.	Remarks.
				Hourly samples in dry weather.	Average of chance samples.				Per square yard per 24 hours.	Per cube yard per 24 hours.		
Hanley - -	Saggars.	$\frac{1}{4}$ in. to $\frac{1}{2}$ in.	5 ft.	—	7·6	54 ?	Sprinkler.	Intermittent.	206	124	Upper part of material requires washing after four or five years.	Six times the dry weather flow dealt with.
Huddersfield -	Clinker.	$1\frac{1}{2}$ ins. to 4 ins.	7 ft.	—	13	77	Sprinkler.	Continuous.	360	155	Good after one year.	Experimental process. Fixed quantity treated daily.
Leeds - -	Coke.	Over $1\frac{1}{2}$ ins.	9 ft. 6 in.	—	18	76	Sprinkler.	Continuous.	200	63	Good after four years.	Experimental process. Fixed quantity treated daily.
Prestolee -	Cinders and gravel.	Fine to coarse.	5 ft.	3·2	—	22	By fine material on surface.	Intermittent.	92	55	Good after eight years. Surface of material is scraped once a month.	Whole of storm water dealt with.
Rochdale - -	Coke.	$1\frac{1}{2}$ ins. to 4 ins.	9 ft.	5·3	—	83	Sprinkler.	Continuous.	424	141	Good after seven years.	Experimental process. Fixed quantity treated daily.
York - -	Clinker.	$1\frac{1}{2}$ ins. to $3\frac{1}{2}$ ins.	6 ft. 6 in.	5·3	—	58	Sprinkler.	Continuous.	360	150	Good after six years.	Fixed quantity treated daily.
Treatment of Precipitation Liquor.												
Chorley - -	Sand, polarite and gravel.	Very fine to coarse.	3 ft.	3	—	50	Flush tank.	Intermittent.	525	525	Good after twelve years. Beds washed by upward flow about once a week.	Rather more than dry weather flow dealt with.
Dorking - -	Clinker.	2 ins. to 4 ins.	5 ft. 7 in.	—	5·5	56	Sprinkler.	Continuous.	392	211	Good after two and a half years.	Experimental process. Fixed quantity treated daily.
Horfield - -	Clinker.	3 ins.	7 ft. 5 in.	2·5	—	36	Stoddart trays.	Continuous.	478	190	Good after five years.	Whole of storm water dealt with.
Leeds - -	Coke.	Over 3 ins.	6 ft.	—	6·3	52	Sprinkler.	Intermittent.	100	50	Unchanged after nine months.	During storms rate of filtration was largely increased.
Normanton -	Sand, polarite and gravel.	Very fine to coarse.	3 ft. 3 in.	14·0	—	112	By fine material on surface.	Intermittent.	106	98	Good after ten years. Filters are brushed over after each application of tank liquor and washed by upward flow every three months.	Fixed quantity treated daily.
Withnell - -	Sand, polarite and gravel.	Very fine to coarse.	3 ft.	2·0	—	81	Flush tank.	Intermittent.	68	68	Good after seven and eleven years. Beds raked over every week and washed by upward flow two or three times a year.	Some storm water dealt with.

NOTE.—The calculated "strengths" of the above sewage liquors are only to be taken as approximate and this more especially in the case of the sewages, etc., from Birmingham, Hanley, Huddersfield and Leeds; at those places the 4 hours "oxygen absorbed" figure is obtained with *weak* permanganate and we have only been able to make an *average* allowance for this.

Methods of Feeding Percolating Filters.

156. The main object to be aimed at in feeding a percolating filter is to deliver the liquid uniformly over the whole area in such a way that each particle of material receives an equal quantity of liquor.

A distributor should comply with the following requirements :—

It should distribute the liquid uniformly over the whole filtering area ;

Its working should not be affected by atmospheric conditions, such as wind, frost, etc. ;

It should be capable of adjusting itself to large variations in the flow, *i.e.*, it should deliver equally well the small flow of night sewage and the increased flow during storms.

The distribution should not be liable to be affected by the stoppage of small holes by the suspended matter of the sewage or tank liquor ;

It should be easy to clean ;

The points at which the moving parts of the distributor are in contact with the stationary parts, or with the parts which have a different motion, should, as far as possible, be separated from the liquid which is being distributed.

In selecting a distributor, it would be necessary to consider the head of water, or other power required to work it, and, of course, the question of cost.

157. At the places which we have had under observation we have had experience of six forms of distribution. We have made no comparative tests of the various forms, and we therefore only propose to offer certain general observations in regard to them.

The forms of which we have had experience may be classified as follows :—

(1) A sprinkler which moves, either automatically or by applied power, dropping or spraying the liquid as it rotates or travels backwards and forwards over an area of filtering material ;

(2) A stationary form of distributor, in which the liquid to be distributed is carried over the filter area by means of pipes, and forced under head of water through a large number of small orifices, so that it is broken up into fine jets ;

(3) A form of distribution in which definite volumes of liquid are automatically delivered in flushes ;

(4) Distribution by means of a very fine material laid on the surface of the filter, the liquid being by this means spread over the whole, or the greater part, of the filtering area ;

(5) Dripping trays, a stationary form of distributor, invented by Mr. F. Wallis Stoddart, by which the sewage liquid is carried over a filtering area in perforated trays of corrugated iron, from which it falls upon the filtering material in a succession of drips ;

(6) Tipping troughs. A stationary form of distributor, consisting of troughs balanced on pivots in such a way that, when filled with liquid, they tip and then return to their original position.

Type No. 1.—As regards moving sprinklers we may make the following observations :—

(*a*) Unless driven by applied power, which must obviously increase the cost of distribution considerably, they are seriously affected in their distribution by wind, and by severe frost and snow. In the case of light revolving sprinklers, they are not infrequently brought to a standstill by the wind. Where the filter is a small one, this disadvantage may to a considerable extent be overcome by building wind screens round the filter or by raising the retaining walls, but on a large works we should think that this would be impracticable, and with large filters not very effective.

(*b*) Automatic revolving sprinklers, when used intermittently (*i.e.*, when fed from a flushing tank), are capable of adjusting themselves to large variations of flow, but when used continuously, without a flushing tank, their rates of working can only be varied within somewhat narrow limits.

(*c*) The forms of sprinkler in which the tank liquor is delivered to the bed through a number of small holes need a considerable amount of attention. The arms require to be brushed out at least once a day, unless the tank liquor happens to be exceptionally free from suspended matter, or not likely to produce fungoid growths.

Type No. 2.—Distribution by means of perforated pipes or nozzles laid over a filtering area is almost always rather unequal, and this would be a disadvantage, except in the case of fairly deep beds constructed of fine or medium material, or deep beds (say, eight feet or more) of coarse material. This method of distribution, moreover, needs a considerable head of liquid for proper working, and also requires constant attention to keep the pipes and distributing holes clean and free.

At Birmingham, where the nozzle form of distributor is in use on a large scale, for each acre and a half of filter one man is constantly employed night and day in cleaning the nozzles. The constant walking over the surface of a filter is a distinct drawback, but assuming that the occupation is not dangerous to the workman, we think that this method of distribution will, in many cases, be found efficient and cheap.

Watson, 25008. Mr. Watson, of Birmingham, has made a careful comparison of various methods of distribution, and it will be seen from his evidence that, on account of cost, he prefers the system of spraying nozzles to other forms of distribution.

Type No. 3.—This method of distribution would only be suitable in a limited number of cases. Where the distribution is by means of flushes, the upper part of the bed should be made of very fine material, such as sand. With this type of filter the surface has to be constantly washed and cleaned, and it is therefore important that the tank liquor should be comparatively free from suspended matter. Owing to the difficulty of obtaining from a strong sewage a tank liquor containing only a small quantity of suspended and colloidal matter, this type of distribution is not well adapted for cases in which strong sewage has to be treated.

Type No. 4.—The distribution obtained by spreading the liquid to be treated over a filtering area covered with a layer of very fine material, such as soil, sand, or clinker dust, etc., does well either for strong or weak sewages; but unless the fine material on the surface of the bed is kept closely packed, there is danger, when the bed is first brought into use, of the liquid passing too rapidly to the drains. It would seem advisable, therefore, where this method of distribution is adopted, that the filter should be constructed throughout of fine to medium material, except round the drains.

Types Nos. 5 and 6.—Tipping troughs and dripping trays are, in our opinion, more suitable for small than for large installations. They can adapt themselves to large variations of flow, and in the case of small or medium-sized works, where constant supervision is not available, this is a great advantage. We may add that these trays are better suited for the distribution of a large volume of weak liquid than a small volume of strong liquid.

The distribution is seldom perfect by either of these forms of distributor, and consequently it is advisable to have deep beds where they are adopted. Further, owing to the fact that the delivery of liquid in both cases is more or less constant, medium-sized or coarse material should be used, to prevent ponding.

A certain amount of supervision is necessary as a tray may become blocked or a trough may fail to tip. The trays would require to be looked at about once a day, we think, and tipping troughs about twice a day ; but, beyond this, little attention is required. The distribution in both these forms is divided up into a number of units, and it is very unlikely that more than one or two units would get out of order at a time and that the distribution would be bad over a whole filtering area.

That tipping troughs are liable to be completely put out of action by severe frost we have seen exemplified at Little Drayton, and although we have had no experience of the same kind with regard to the trays, we should think that these were also liable to be affected by severe frost, though in their case distribution would never cease altogether.

Risk of Nuisance.

158. All forms of distribution on percolating filters are liable to give rise to nuisance from smell, if a strongly smelling liquor has to be dealt with. In the case of trays or tipping troughs the smell is confined more or less to the immediate vicinity of the filter, and it may be largely done away with at small works by providing an inexpensive form of cover for the filter. The nozzle form of distributor is naturally the most liable to give rise to smell, but moving sprinklers are almost equally bad in this respect.

Some Observations on the Most Convenient Superficial Area for a Percolating Filter.

159. So long as due regard is had for economy, the main consideration in laying out an area of percolating filters is to arrange the area so that portions of it may be put out of work without interfering with the general working of the plant.

If, for instance, at a small sewage works the whole of the sewage was treated upon one percolating filter fed by one sprinkler, any stoppage of that sprinkler would, unless land or some other means of disposal were available, result in the temporary discharge of a large quantity of unpurified sewage into the watercourse.

Experience has not shown that it is **necessary* for purposes of aeration to expose the sides of a percolating filter to the atmosphere, in order to obtain good results, and there would seem to be no reason, beyond engineering considerations, such as configuration of site, etc., for splitting up an area of percolating filter into units, provided that any part of that area could be cut out and rested, when necessary, without interfering with the general purification. The particular arrangement of the works would therefore depend very largely upon the form of distributor employed.

The size of a revolving distributor, for instance, has economic limits, and if this method of distribution were adopted the filter area would have to be split up into units corresponding with these limits.

The method of distribution by flushing fixed quantities of sewage liquid over percolating filters, constructed with a surface layer of very fine material, necessitates that the filter units should be small. Otherwise the flush of liquor cannot be made to spread evenly over the whole surface of the filter. This kind of filter has also to be washed or scraped at short intervals of time, and allowance must consequently be made for this.

Distribution by a power-driven distributor moving over a rectangular bed also has its limits, for, although the working of such a distributor can be regulated so as to rest the ends of a rectangular bed, it would appear to be difficult to feed the

* Some experiments which we carried out at Hendon, with the Ducat filter, indicated that open sides may be of advantage for the treatment of crude-screened domestic sewage, on a rather fine perolating filter Other work has prevented us from completing these experiments.

ends while resting the middle portion of the area. Further, if the bed were *very* long, large quantities of liquor would have to be fed on to each portion of filter at long intervals of time, instead of small quantities at short intervals.

With stationary distribution by means of nozzles, perforated pipes, dripping trays or tipping troughs, there would appear *in principle* to be no limit of size, for portions of a large area fed by such means could be cut out or brought in at will, without interfering with the general purification.

Where moving sprinklers are used, it would be cheaper to limit the number of units to a minimum, but the whole filtering area should comprise not less than three units so as to allow of cleaning and resting.

In the arrangement of a percolating filter area at a very large works, other considerations would have to be taken into account, such, for example, as the size of feed pipes, and the distance which the workmen would have to walk upon the material in order to get at different parts of the filter.

In regard to this question we may refer, particularly, to the evidence of Dr. Fowler, 23020, Mr. Watson, 25015, Dr. Reid, 24432 (131), and Messrs. Willcox and Raikes, 26114.

Construction of the Base of Percolating Filters.

160. In a percolating filter of *coarse* material, large quantities of suspended matter quickly work their way through the filter. If this suspended matter is not allowed to come away with the effluent, the bottom layers of the filter will become choked, and this will interfere with the working of the filter, not only for mechanical reasons, but also by preventing aeration. In such a filter, therefore, it is necessary to make provision for the free passage of suspended matter through the material and into the effluent drains, so that it can be completely carried away from the bed and dealt with subsequently.

In a percolating filter of *medium* or *fine* material, where the bulk of the suspended matter is caught and held in the upper part of the filter, the free base would not seem to be an absolute necessity. If, however, the suspended matter is not removed from the upper part of the filter by washing or riddling, it will eventually find its way to the bottom of the filter.

In any case the working of a percolating filter depends primarily upon the free passage of air through the bed, and, for this reason, we should say, in general, that it is advisable to construct the lower portions of all percolating filter, fine as well as coarse, as open as possible

If, in a filter constructed of medium or fine material, a bottom layer of large pieces is relied upon wholly for the aeration of the bed and for the free passage of liquid to the drains, it is obvious that great care must be taken in selecting this coarse material. Any serious disintegration at the bottom of the filter would result in parts of the filter becoming water-logged.

Choking of Percolating Filters.

161. Unless the material is coarse enough to allow the free passage of suspended matter, percolating filters are liable to become choked. Within ordinary practical limits, the rate of choking would depend upon the actual quantity of suspended matter delivered to the surface of the bed. At Leeds, for instance, it was found that carefully screened sewage, containing 80 parts of suspended matter per 100,000, when put upon a percolating filter composed of clinker $\frac{3}{8}$ inch to $\frac{5}{8}$ inch diameter, ten feet deep, had the effect of completely choking the surface within a month, notwithstanding the fact that the rate of filtration never exceeded 25 gallons per cube yard per day. When, however, septic tank liquor containing only about 18 parts of suspended matter per 100,000 was substituted for the screened sewage, the same filter gave good results without clogging for two years, though the rate of filtration was doubled. At the end of that time it was necessary to rest the bed and fork the surface, and after three years, owing to internal clogging, it became necessary to stop the experiment.

If a clogged filter of medium or fairly coarse material is rested, the suspended matter which causes the choking becomes granular, and can eventually be washed out of the filter. To some extent this applies also to a filter composed of very fine material, but in that case by far the greater proportion of the suspended matter remains on or near the surface and can only be got rid of by removing the clogged material and washing it, or exposing it for some time to the air, and eventually riddling it dry. When coarse material is used in a percolating filter there is apparently little danger of the filter becoming clogged, unless the sewage contains much fibre or is liable to give rise to fungoid growths, or unless serious disintegration of the material takes place. We have had no experience of such a filter becoming clogged with suspended matter when dealing with domestic sewage. At Accrington, coarse percolating filters have been in use for the treatment of septic tank liquor for eight years, and have not clogged. At Horfield, a coarse percolating filter treating precipitation liquor and fed by means of dripping trays ran uninterruptedly until it was dismantled after five years' work. At York, coarse filters have been in use for the treatment of septic tank liquor, without interruption, for four years. There are, in fact, a number of such instances. This kind of filter, however, seems to be liable to choke as the result of surface growths (*see* page 97). Where there is much fibre in the liquid to be treated (and the same thing would no doubt apply to grease and hops, etc.), percolating filters of even very coarse material may choke up. At Leeds, a percolating bed which was constructed of coarse coke, showed signs of becoming choked after having received septic tank liquor for eight and a half months. The primary cause of the choking was, we think, the fibrous character of the suspended matter, but there was a considerable development of growth on the surface of this bed at the same time.

The choking of a percolating filter constructed of medium-sized material (say $\frac{1}{4}$ inch to $\frac{5}{8}$-inch diameter) takes place at or near the surface, the material below this remaining fairly clean. We have seen examples of this at Salford, Hanley, Chesterfield, Birmingham, and Hendon, though at none of these places was the choking serious. At Market Drayton and Leeds, however, the upper portions of the filters had to be washed or renewed after about three years' work. The following table shows the amount of suspended matter, the rate of filtration, and the condition of the filters at the above places :—

Place.	Nature of material.	Size of material.	Amount of suspended matter in tank liquor treated. Parts per 100,000.	Rate of filtration in gallons.		Condition of filters.
				Per square yard per 24 hours.	Per cube yard per 24 hours.	
Leeds - - -	Clinker	$\frac{3}{8}$ in. to $\frac{5}{8}$ in.	80	83	25	Clogged after 1 month.
Market Drayton -	Granite	$\frac{3}{8}$ „ $\frac{3}{4}$ „	25	50	20	Upper part of material required washing after about 4 years' work.
Hendon - -	Clinker	$\frac{1}{2}$ „ $\frac{3}{4}$ „	20	125	40	Good after 8 years.
Leeds - - -	„	$\frac{3}{3}$ „ $\frac{5}{8}$ „	18	200	57	Bed seriously clogged after $2\frac{1}{2}$ years.
Chesterfield -	„	$\frac{1}{4}$ „ 2 „	12	90*	40*	Good after 6 years.
Birmingham -	Broken brick and granite	$\frac{1}{2}$ „ 3 „	8	155	77	Good after 3 or 4 years.
Hanley - -	Saggars	$\frac{1}{4}$ „ $\frac{1}{2}$ „	5	206	124	Upper part of material would probably require washing every 4 or 5 years.
Salford - -	Clinker	$\frac{3}{16}$ „ $\frac{3}{4}$ „	3	318	151	Good after 5 years. Top foot of material renewed on 10 per cent of area after 3 or 4 years, and rest of area dug over.

* Dry-weather rates of flow. In storm times these filters take four times the dry-weather flow.

We have had no experience of the washing of percolating-filter material on a practical scale ; but, from the evidence given as to the cost of washing contact-bed material, we should estimate that the cost would be approximately 1s. 6d. to 2s. 6d. per cube yard, if done by machinery on a large scale, and from 2s. 6d. upwards per cube yard, if done by hand on a small scale.

Growths on Percolating Filters

162. At a number of places thick, gelatinous, fungoid growths have at certain periods of the year (usually in the winter or early spring) developed upon the surfaces of percolating filters to such an extent as to cause serious ponding and consequent deterioration of the filter effluent. On the other hand, at other places, where apparently similar growths are present in small quantities on the surface of the material, they do not increase to any marked extent, and no ponding arises from this cause. Tables I. and II. give examples of each kind of place.

TABLE I.—Places where growths upon the surface of percolating filters have caused trouble.

Place.	Material used in filter.	Size of Material.	Mode of Distribution.	Whether delivery of liquor is continuous or intermittent.	Kind of liquor treated.	Amount of suspended matter in the liquor. Parts per 100,000.	Remarks as to growths.
Dorking	Clinker.	Coarse to medium.	Sprinkler.	Continuous.	Precipitation liquor.	8	The filters were started on Nov. 16th, 1905, and a pinkish-yellow filamentous growth made its appearance a fortnight later. This flourished until May of the following year, when it died away. During the last five weeks of this period the effluent from the filter was bad.
	Clinker.	Coarse to medium.	Sprinkler.	Continuous.	Septic tank liquor.	8·1	In both these cases, a grey-brown amorphous growth made its appearance at the same time as the growth on the filter treating precipitation liquor, but it did not flourish to such an extent, and never interfered seriously with the working of the filter. It practically disappeared during the early part of May.
	Clinker.	Coarse to medium.	Sprinkler.	Continuous.	Settled sewage.	10·5	
Guildford	Coke.	Coarse.	Sprinkler.	Intermittent.	Septic tank liquor.	15·9	This experimental filter was started in August, 1906. A grey-brown filamentous growth appeared on surface of the coke during the last months of that year, and increased seriously after frosty weather in January, 1907. The growth began to die away in the early summer.
Kingston	Clinker.	Coarse.	Sprinkler.	Continuous.	Precipitation liquor.	1·5	A short fibred grey growth appears annually on the surface of the filter, commencing about November and dying off in March. In the winter months it forms an almost impervious mat on the surface of the filter, the effluent becoming bad in consequence.
Leeds	Clinker.	Coarse.	Sprinkler.	Continuous.	Septic tank liquor.	18	The filter was started on March 9th, 1899, and ran till May 8th of the same year, when the effluent deteriorated in quality owing to the bed having become covered with an abundant gelatinous mycelium-like growth (pylobolus). On July 10th some very coarse coke was put on the surface of the bed, and from that time it was found possible to run for periods of about three months before the surface choked with the growth. When this occurred the coke was simply forked over.
	Clinker (6 inches of gas coke on surface).	Very coarse.	Sprinkler.	Continuous.	Crude sewage.	5·3	The filter was started on December 23rd, 1901. Almost from the first trouble arose from the thick pylobolus growth forming on the surface; this closed the interstices of the gas coke, and so gave rise to ponding and bad distribution. On March 1st, 1902, the coke was removed, and the bed from that time gave good results until the winter of 1902–3, when choking again occurred.

TABLE II.—Places where percolating filters have been run without any trouble from growths.

Place.	Material used in filter.	Size of material.	Mode of distribution.	Whether delivery of liquor is continuous or intermittent.	Kind of liquor treated.	Amount of suspended matter in the liquor. Parts per 100,000.	Remarks as to growths.
Accrington	Clinker	Coarse	Sprinkler	Continuous	Septic tank liquor	19	Only very slight signs of growth on the surface of the material after six years' work.
Birmingham	Clinker	Coarse to fine	Nozzles	Intermittent	Septic tank liquor	7·3	Only slight signs of growth after a year.
	Broken brick	Coarse to fine	Nozzles or sprinkler	Continuous or intermittent	Septic tank liquor	7·3	Only slight signs of growth after a year.
	Broken granite	Coarse to fine	Nozzles or sprinkler	Continuous or intermittent	Septic tank liquor	7·3	Only slight signs of growth after a year
Chorley	Sand	Very fine	Flushing tank	Intermittent	Precipitation liquor	2	No growth after eight years. Filters washed every week.
Hanley	Saggars	Fine	Sprinkler	Intermittent	Septic tank liquor	4·4	No growth after four years.
Horfield	Clinker	Coarse	Dripping trays	Continuous	Precipitation liquor	2·5	No growth after four years
Huddersfield	Clinker	Coarse to medium	Sprinkler	Continuous	Septic tank liquor Precipitation liquor Settled sewage	13·1 7·0	No serious signs of growth on any beds.
York	Clinker slag, coke, broken brick	Coarse to medium	Sprinkler	Continuous	Septic tank liquor	5·3	No growth after four years.

163. So far as we are aware, such growths have not been made the subject of systematic study in connection with sewage disposal, and little appears to be known as to the conditions under which they flourish. As will be seen from Table I., however, a pylobolus growth appeared upon the surface of a percolating filter treating septic tank liquor at the Leeds sewage works. In their Report on Experiments in Sewage Disposal, City of Leeds, 1905, p. 140, Colonel Harding and Mr. Harrison make the following remarks on the subject :—

"A few words must be added in regard to the difficulty of the fungoid "growths which arise in dealing with Leeds sewage on percolating filters, and "which, with any but very coarse material, soon choke the air spaces, and cause "the sewage to pond on the surface. The growths were less with partly settled "sewage than with the crude sewage and as in other cases they did not spread far "down into the filter, not more than from 6 to 12 inches at the most, it would "seem that light is required for their development."

"On the other hand, the holes in the sprinkler tubes were constantly choked "with these growths, so that they required to be daily cleansed; but it is more "likely that this was due to the fungus which forms in the open channels leading "to the sprinkler being washed forward into the tubes than to the growths arising "in the tubes themselves. It is quite possible that sewage thoroughly well settled "may give rise to fungoid growths, the detritus from which may cause suspended "matters to appear in a filtrate."

"The question of these growths and the circumstances which favour their "devolopment is one that should be further investigated."

164. As the use of percolating filters is likely to spread in the future, we are impressed with the need for practical experiments which have for their object either the prevention or the destruction of the growths on the surfaces of such filters.

That growths of this kind can be destroyed is shown by an experiment (suggested by Dr. Houston and Mr. Colin Frye) recently carried out on a small scale upon the surface of one of our experimental filters at Dorking. In March, 1907, the surface of this filter (which at that time treated septic tank liquor) was covered with a considerable layer of gelatinous growth, sufficient to cause local ponding in the tracks of the sprinkler jets. On March 16th the filter was rested for twenty-four hours in dry weather, and at the end of that time the surface was divided up into eight equal segments (1.6 square yards each), and seven of these were treated with the following reagents, the eighth segment being left untouched :—

(1) Powdered quicklime.
(2) Bleaching powder.
(3) A 20 per cent. solution of "Chloros."
(4) A 20 per cent. solution of copper sulphate
(5) A 20 per cent. solution of ferrous sulphate.
(6) A 20 per cent. solution of caustic soda.
(7) A 20 per cent. solution of sulphuric acid.

In the case of (1) and (2), sufficient of the dry solid was used to cover the surface with a fine layer of powder, while in the case of the other five segments one litre of each solution was applied to the material with a brush, the filter being then left resting for a further period of twenty-four hours.

At the end of this time, the segment which had been treated with caustic soda had undergone a distinct change in appearance, the clinker being perfectly clean on the upper side, though the under side was still covered with a slimy layer of half-dissolved growth. Of the other six segments, none showed any marked destruction of the growth, but the copper and iron sulphates had stained their segments green and rusty brown respectively. The filter was started again at 3 p.m. on the same day. A very large quantity of coarse brown solid matter (20 to 30 parts per 100,000) came away in the filter effluent during the first hour, but the quantity gradually decreased to about 6

parts per 100,000 after 24 hours. The samples taken during the first hour went putrid upon incubation, this being no doubt chiefly due to the outflush of solids, but otherwise the working of the filter was not seriously upset, though the nitric nitrogen in the effluent fell from 2 parts to 1 part per 100,000 for some days, eventually rising again to 2 parts on March 25th.

On April 22nd there were again signs of local ponding on the surface of the filter, but the growth on that segment which had been treated with caustic soda was considerably less than on the other segments. It was therefore thought desirable to try the application of a 20 per cent. solution of caustic soda to the whole surface of the filter. This was accordingly done, two gallons of the solution being used for the purpose. The procedure otherwise, *i.e.*, as regards the resting of the filter, was exactly the same as in the first experiment.

On the following morning the surface of the clinker was covered with a white deposit of sodium carbonate, and, on re-starting the filters shortly afterwards, a great quantity of dark brown solid matter came away in the effluent. Samples of effluent drawn for the first two hours readily putrified upon incubation. After twenty-four hours the effluent when freed from solid matter was normal, but a large quantity of suspended solids continued to come away with the effluent for about a week.

As in the case of the first experiment, the working of the filter, apart from the flush-out of solids, was not seriously upset, and after the first two hours from the restart there was no fall in the figure for oxidised nitrogen.

The exposed surface of the clinker was completely cleaned by this application of caustic soda solution, though a considerable amount of growth still adhered to the under side of the larger pieces of material. All ponding, however, disappeared, and no further growth of any consequence made its appearance for some months. The cost of the treatment, including labour, was 2½d. per square yard, but this would no doubt be materially reduced when carried out on a large scale.

Probably three such applications of 20 per cent. caustic soda would be necessary to keep the growth down during the winter or early spring months on the filter at Dorking.

165. Generally speaking growths do not appear to flourish on the surface of percolating filters constructed of fine material, but whether this is due to the size of the material or to the fact that filters of fine material are usually fed intermittently, we cannot say. Colonel Harding and Mr. Harrison, in an experiment at Leeds, found that they could keep down growth on a coarse-grained filter by substituting an intermittent sprinkler for a continuous one.

Our experiments seem to indicate that growths flourish most on filters treating precipitation liquor. This suggests that the use of chemicals (especially soluble sulphates) may influence their development, but, on the other hand, precipitation liquor usually contains considerably less suspended matter than other tank liquors, and a larger volume of it is for this reason generally treated per cube yard.

As regards the growths in channels along which effluents flow, they seem to require, for their development, an aerated but still unpurified sewage liquid, and it is possibly for this reason that they are generally more abundant in channels conveying dilute sewage liquids than in channels conveying strong sewage liquids, especially if the suspended matter is removed.

Some Observations as to the Relative Cost of Contact Beds and Percolating Filters.

166. On pages 36–43 of this Report we have made some observations on the relative cost and efficiency of preliminary processes for the removal of suspended matters from sewage, and we propose here to make a similar comparison between the two types of artificial filter usually adopted for the further purification of the sewage, and commonly known as "contact beds" and "percolating filters." As in the case of the preliminary processes, the cost of filters necessarily varies with local conditions, and no figures can be given which would be generally applicable. Following the plan adopted in the case of the preliminary processes, however, we propose to compare the two types of filters in a hypothetical case in which we assume :—

That ample fall is available ;

That the sewage is of a normal domestic character and of average strength ; *i.e.*, a sewage which would require about 100 parts of oxygen,* by weight, for the oxidation of the organic matter contained in 100,000 parts of sewage ;

That the flow of sewage is 1,000,000 gallons per day in dry weather ;

That in times of storm twice the dry weather flow is passed through the filters.

For the purpose of this comparison, we assume that the sewage has been subjected to preliminary tank treatment for the removal of suspended matter, and that in each case a satisfactory final effluent is to be produced.

We have not considered it necessary to compare the costs of all the modifications of percolating filters and contact beds of which there are examples, but have confined our comparion to percolating filters of coarse material, nine feet deep, and contact beds composed, for the most part, of medium-sized material, but having rather coarse material round the drains and a layer of fine material on the surface.

Mr. G. B. Kershaw, our Engineer, has prepared detailed drawings of the two kinds of filter, when used in conjunction with each of five different tank treatments, and, from these drawings has taken out quantities. The filters are all assumed to have been constructed on the same basis. The concrete flooring for the percolating filters, for example, has been assumed to be practically the same thickness as the concrete flooring for the contact beds, and the cost of concrete has been taken at a fixed price throughout. The class of work has been taken to be of the best kind, the walls and the floors of the contact beds, for instance, being made thoroughly water-tight by rendering with cement. It is due mainly to this fact that our estimates for the cost of contact beds are high. At some places a cheaper form of construction than we have assumed has been adopted. At Burnley, for instance, no concrete was used, and the beds, which are 3 feet in depth, cost approximately £1,300 per acre. At Manchester, where concrete was used, but where no rendering was done, the cost amounted to between £2,500 and £3,000 per acre for beds of the same depth. In Mr. Kershaw's estimates, the cost is about £5,700 per acre.

167. The working capacities of both contact beds and percolating filters depend to a large extent upon the strength of the liquor passed on to them and the amount of suspended matter contained in such liquor. In the following table, the strength of the tank liquor which is produced from our hypothetical sewage by each of the five preliminary processes, the amount of suspended matter in the liquor in each case, and the rate of filtration in each type of filter, are given :—

* This would generally be equivalent to about 10 or 12 parts per 100,000 of "oxygen absorbed" in four hours from strong permanganate.

Preliminary Process.	Strength of Tank Liquor, stated in parts by weight of oxygen per 100,000 required for the oxidation of the organic matter.	Amount of Suspended Matter in Tank Liquor (parts per 100,000).	*Contact Beds.		*Percolating Filters.	
			Rate of Filtration per cube yard per day (dry weather flow).	Cubic Content of Filtering Material required to treat one million gallons per day (dry weather flow).	Rate of Filtration per cube yard per day (dry weather flow).	Cubic Content of Filtering Material required to treat one million gallons per day. (dry weather flow).
			Gallons.	Cubic yards.	Gallons.	Cubic yards.
Quiescent settlement, with chemicals.†	50	1 to 4	140	7,143	175	5,714
Continuous flow settlement, with chemicals.	60	3 to 6	85	11,765	150	6,666
Quiescent settlement, without chemicals.	70	5 to 8	55	18,182	100–125	8,928
Continuous flow settlement, without chemicals.	80	10 to 15	40	25,000	75–100	11,494
Septic tanks - - -	80	10 to 15	40	25,000	75–100	11,494

Initial Cost of Contact Beds and Percolating Filters.

168. The following table gives Mr. Kershaw's estimates of the constructional cost of percolating filters and contact beds required to treat a dry weather flow of 1,000,000 gallons per day of our hypothetical sewage on the above basis. The estimates include the sum of 15 per cent. for engineering and contingencies.

Preliminary Process.	Contact Beds.	Percolating Filters.
	£	£
Quiescent settlement, with chemicals - - - -	8,527	7,376
Continuous flow settlement, with chemicals - - -	14,898	8,836
Quiescent settlement, without chemicals - - - -	22,080	10,596
Continuous flow settlement, without chemicals - -	26,846	13,824
Septic tanks - - - - - - - - - -	26,846	13,824

The principal items in the estimates for both kinds of filters are: filtering medium, concrete in walls and floors and rendering; and excavation in the case of the contact beds.

The figures for these items are given in the following tables:—

Contact Beds.

Preliminary Process.	Cost of Filtering Medium.	Cost of Concrete in Floors and Walls.	Cost of Rendering.	Cost of Excavation.
	£	£	£	£
Quiescent settlement, with chemicals - -	3,777	2,545	675	Single set of beds; very little excavation. ‡
Continuous flow settlement, with chemicals -	3,545	3,882	1,350	885
Quiescent settlement, without chemicals - -	5,431	5,461	1,650	1,204
Continuous flow settlement, without chemicals.	7,231	7,038	2,171	1,722
Septic tanks - - - - - -	7,231	7,038	2,171	1,722

* The quality of the effluents produced by the ten plants would, of necessity, not be identical. The average quality as expressed in terms of oxidizability of effluent (see paragraphs 178 and 179) would be something like +2 for the double contact effluents and—2 for the percolation effluents.

† In the case of quiescent settlement with chemicals, we have allowed for single contact only; in the other cases, for double contact.

‡ We have assumed in our hypothetical case that the primary beds are practically out of ground, and that excavation is required only in the case of the secondary beds.

Percolating Filters.

Preliminary Process.	Cost of Filtering Medium.	Cost of Concrete in Floors and Walls.	Cost of Rendering.
	£	£	£
Quiescent settlement, with chemicals	1,951	2,617	269
Continuous flow settlement, with chemical	2,431	3,271	336
Quiescent settlement, without chemicals	4,375	5,889	605
Continuous flow settlement, without chemicals	5,833	7,851	806
Septic tanks	5,833	7,851	806

Effluent Settling Tank.

169. In our hypothetical case, a tank is provided for the settlement of the effluent from the contact beds, as well as from the percolating filters. Some means are needed in the case of coarse percolating filters for the settlement of the effluent solids; and in the case of the contact beds we have assumed that a tank was required for the purpose of rendering the discharged liquid uniform in quality, and thus preventing the possible discharge of a putrescible effluent during the first flush, and, more especially, of putrescible solids. The effluent tank is of the Dortmund type, having a capacity of about 84,000 gallons, so as to provide for a stay in the tank of about two hours in each case. The total cost of this tank is calculated to be £682.

Loan Charges.

170. The following table gives the area and the assumed cost of the land occupied by the installations.

We have taken the price of land throughout at £100 per acre.

Preliminary Process.	Contact Beds.		Percolating Filters.	
	Land required (acres).	Cost of Land.	Land required (acres).	Cost of Land.
		£		£ s. d.
Quiescent settlement, with chemicals	1·26	126	0·73	73 0 0
Continuous flow settlement, with chemicals	2·03	203	0·91	91 0 0
Quiescent settlement, without chemicals	3·21	321	1·095	109 10 0
Continuous flow settlement, without chemicals	4·18	418	1·46	146 0 0
Septic tanks	4·18	418	1·46	146 0 0

Assuming that the loan is raised at 3½ per cent. interest per annum, and is repayable in equal annual instalments over a period of thirty years, the annual loan charges on the complete installations would be as follows :—

Preliminary Process.	Contact Beds.		Percolating Filters.	
	Loan charges in respect of Contact Bed Installation.		Loan charges in respect of Percolating Filter Installation including charges in respect of sprinklers.	
	Per annum.	Per million gallons (dry weather flow).	Per annum.	Per million gallons (dry weather flow).
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Quiescent settlement, with chemicals	507 3 9	1 7 10	470 19 7	1 5 10
Continuous flow settlement, with chemicals	858 4 0	2 7 0	558 11 3	1 10 7
Quiescent settlement, without chemicals	1,255 2 9	3 8 9	662 9 2	1 16 3
Continuous flow settlement, without chemicals	1,519 6 3	4 3 3	854 8 5	2 6 10
Septic tanks	1,519 6 3	4 3 3	854 8 5	2 6 10

Labour and Supervision.

171. For the contact bed installations, we assume that the services of two men (one for the day and one for the night) would be required, and for the percolating filter installations, the services of one man.

Taking the labourer's time at 21s. a week, and including one-third of the manager's time at a salary of £130 per annum (say, £43), the cost of labour and supervision in connection with the installations would be as follows :—

Preliminary Process.	Contact Beds.		Percolating Filters.	
	Per annum.	Per million gallons (dry weather flow).	Per annum.	Per million gallons (dry weather flow).
	£	s. d.	£	s. d.
Quiescent settlement, with chemicals	152	8 4	98	5 4½
Continuous flow settlement, with chemicals	152	8 4	98	5 4½
Quiescent settlement, without chemicals	152	8 4	98	5 4½
Continuous flow settlement, without chemicals	152	8 4	98	5 4½
Septic tanks	152	8 4	98	5 4½

Cost of washing and renewing Filtering Medium.

Contact Beds.

172. According to the evidence, which is dealt with in another part of this Report, we find that the average cost of removing, washing, replacing, and making good the material of a contact bed, by machinery, is about 1s. 6½d. per cube yard, exclusive of cost of washing plant.

In the present calculations we assume that the cost per cube yard of washing, etc., is 1s. 7d., and that the material in the primary beds would require washing every four years, and that in the secondary beds every ten years.

On these assumptions, one acre of primary beds, 3 feet deep, would cost £383 every four years for washing and renewal, or about £96 per annum ; and one acre of the secondary beds, £383 every ten years, or £38 6s. per annum.

Percolating Filters.

173. So far as our experience of percolating filters of coarse material has gone, we think it may be taken that the material of these filters will last for a very long period of time, if a few inches on the top of the filter are removed and renewed occasionally. At Accrington, Rochdale, and York, beds of this kind, constructed both of coke and clinker, have been in constant use for eight years. At Horfield a clinker bed, dismantled after five years' use, was found to be in almost the same condition as when it was started. We do not propose, therefore, to add anything to the cost of our percolating filter installations for washing and renewal of material.

Plant special to Percolating Filters.

174. We have assumed that the life of rotary sprinklers treating domestic sewage is ten years, and have therefore calculated the loan charges on this period.

At Accrington the annual cost of repairs to an automatic rotary sprinkler, taken over a period of three years, was found to average 18s. 4d. In our calculations, we have taken the cost of repairs at £1 per sprinkler per annum.

The following table shows our estimates of the cost of washing contact bed material. and, in regard to percolating filters, the sums required for repairs and loan charges in respect of sprinklers :—

Preliminary Process.	Contact Beds.		Percolating Filters.			
	Annual Charges in respect of Washing and Renewal of Beds.	Cost per million gallons in respect of Washing and Renewal of Beds.	Annual Loan Charges in respect of Sprinklers based on a ten year period.	Loan Charges in respect of Sprinklers per million gallons (dry weather flow).	Annual Cost of Repairs to Sprinklers.	Cost of Repairs to Sprinklers per million gallons (dry weather flow).
	£ s. d.	s. d	£ s. d.	s. d.	£	d.
Quiescent settlement, with chemicals.	141 2 5	7 9	28 17 2	1 7	4	$2\frac{1}{2}$
Continuous flow settlement, with chemicals.	169 8 6	9 3	36 1 6	2 0	5	$3\frac{1}{4}$
Quiescent settlement, without chemicals.	266 10 1	14 7	43 5 9	2 $4\frac{1}{2}$	6	$3\frac{3}{4}$
Continuous flow settlement, without chemicals.	360 18 4	19 9	57 14 5	3 2	8	$5\frac{1}{4}$
Septic tanks - - -	360 18 4	19 9	57 14 5	3 2	8	$5\frac{1}{4}$

Total Cost for Filtration alone.

175. The total cost of the contact bed and percolating filter installations, including loan charges, labour and supervision, etc., according to the foregoing calculations, would be as follows :—

Preliminary Process.	Contact Beds.		Percolating Filters.	
	Per Annum.	Per Million Gallons (dry weather flow).	Per Annum.	Per Million Gallons (dry weather flow).
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Quiescent settlement, with chemicals -	800 16 2*	2 3 11*	572 19 7	1 11 5
Continuous flow settlement, with chemicals.	1,179 12 6	3 4 7	661 11 3	1 16 3
Quiescent settlement, without chemicals	1,673 12 10	4 11 8	766 9 2	2 1 11
Continuous flow settlement, without chemicals.	2,032 4 7	5 11 4	960 8 5	2 12 8
Septic tanks - - - - -	2,032 4 7	5 11 4	960 8 5	2 12 8

* Single contact assumed in this case.

Total Cost of Complete Treatment.

176. The total cost of each of the preliminary processes has been shown in another part of this Report. Adding this to each of the filtration processes, we arrive at the following figures for the total cost of the complete treatment of a dry weather flow of 1,000,000 gallons of sewage per day.

Per Annum.

Preliminary Process.	Contact Beds.			Percolating Filters.		
	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Complete Treatment.	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Comp'ete Treatment.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Quiescent settlement, with chemicals.	1,258 0 9	800 16 2*	2,058 16 11	1,258 0 9	572 19 7	1,831 0 4
Continuous flow settlement, with chemicals.	1,134 19 11	1,179 12 6	2,314 12 5	1,134 19 11	661 11 3	1,796 11 2
Quiescent settlement, without chemicals.	724 7 9	1,673 12 10	2,398 0 7	724 7 9	766 9 2	1,490 16 11
Continuous flow settlement, without chemicals.	564 12 8	2,032 4 7	2,596 17 3	564 12 8	960 8 5	1,525 1 1
Septic tanks - - -	629 4 11	2,032 4 7	2,661 9 6	629 4 11	960 8 5	1,589 13 4

Per Million Gallons (dry weather flow).

Preliminary Process.	Contact Beds.			Percolating Filters.		
	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Complete Treatment.	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total cost of Complete Treatment.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Quiescent settlement, with chemicals.	3 8 11	2 3 11*	5 12 10	3 8 11	1 11 5	5 0 4
Continuous flow settlement, with chemicals.	3 2 2	3 4 7	6 6 9	3 2 2	1 16 3	4 18 5
Quiescent flow settlement, without chemcals.	1 19 8	4 11 8	6 11 4	1 19 8	2 1 11	4 1 7
Continuous flow settlement, without chemicals.	1 10 11	5 11 4	7 2 3	1 10 11	2 12 8	4 3 7
Septic tanks - - -	1 14 6	5 11 4	7 5 10	1 14 6	2 12 8	4 7 2

177. On the basis which we have adopted, purification of sewage (after preliminary treatment) by means of percolating filters costs only about two-thirds as much as purification by double contact beds.

Where, however, the sewage has first been subjected to quiescent settlement, with chemicals, and single contact is sufficient to produce a satisfactory effluent, the cost becomes more nearly equal, though percolating filters are, even in that case, slightly cheaper.

The cost depends, of course, very largely on the kind of construction adopted.

Our estimates for the cost of double contact beds per acre, 3 feet deep, including filtering material, concrete, rendering, drains, distribution channels, engineering and contingencies, etc., amount approximately to £5,700 per acre. If the beds were built by simple excavation and banking, as is permissible in heavy clay soil, the cost would be very considerably reduced.

We have taken the price of filtering material at 6s. per cube yard, placed in position in the beds, which may be considered a fair average, though evidence shows the price has in some cases been much lower. Since this item alone amounts to about £1,396 per acre, 3 feet deep, it is at once apparent how largely the price of filtering material influences the cost of treatment.

* Single contact assumed in this case.

RELATIVE EFFICIENCY OF CONTACT BEDS AND PERCOLATING FILTERS.

178. Sewages vary in composition, not only in regard to the degree of dilution to which they are naturally subjected, but also in regard to the proportion in which different kinds of organic matter are present in them, and we are not aware of any really accurate method by which the work done by different filters, treating different sewages, can be compared.

We have, however, found it convenient to adopt, for the purpose of comparing the results obtained at different places, a unit of purification, which is based on the oxidizability of the sewage and the oxidizability of the filtrate, after giving credit for the oxygen contained in the effluent in the form of nitrate.

This basis for a unit was suggested by Dr. McGowan.

The unit of time we have taken as 24 hours, the unit of quantity as 1 gallon, and the unit of filtering material as 1 cubic yard.

Thus, to express the number of units of purification effected by a filter, we have deducted the number of parts by weight of oxygen taken up by 100,000 parts of the effluent from the filter, from the number of parts by weight of oxygen taken up by 100,000 parts of the liquor going on to the filter. The figure so obtained has been multiplied by the number of gallons of liquor, per cube yard, passing through the filter in 24 hours.

179. In his Memorandum* on the measurement of the strength of sewage, Dr. McGowan has set out reasons for adopting a formula, by which the figure representing the number of parts of oxygen which the sewage will take up can be calculated, with a fair degree of accuracy.

For the purpose of ascertaining the number of parts of oxygen which an effluent will take up, Dr. McGowan has also suggested that, in lieu of carrying out the actual experiment of keeping an effluent until it has become completely oxidized, and actually measuring the amount of oxygen taken up, the amount may be approximately arrived at by a calculation based on other figures of analysis. The formula which he suggests is:

(Ammoniacal *N.* + Organic *N.*) × 4·5 + Volatile matter of suspended solids × 2 – Nitric Nitrogen × 3.

As regards this formula, it is well known that the better an effluent is oxidized, the less change will it undergo on keeping. The work of Dr. Adeney and others has shown that, in the case of good effluents, the figure for organic nitrogen would represent, for the most part, organic matter which had undergone fermentation, and in considering the *quality* of such effluents, e.g., with reference to their effect on streams, we think the figure may generally be neglected.

It is, however, open to question whether, in calculating the work done by a filter, it is not better to include the figure inasmuch as the whole of the organic nitrogen of liquor going on to the filter has been taken into account in calculating, by the empirical formula given on page 16, the strength or oxidizability of that liquor.

The point is further discussed in the report by Dr. McGowan and Mr. Colin Frye on the estimation of work done by filters which is contained in Appendix IV.

Until the calculation method has been compared with the results of direct experiment in a large number of cases, no precise statement as to its value can be made, but we have found it convenient to adopt it in the preparation of this Report.

On this basis the following table has been compiled showing the units of purification effected by the filters at the places indicated.

* Appendix IV.

TABLE SHOWING THE UNITS OF PURIFICATION EFFECTED BY FILTERS.

Place.	Process of Treatment.	Character of Filtering Material.	Amount treated per cube yard of filter per day.	Strength * of Liquor Treated (calculated).	* Strength ‡ of Filter Effluent (calculated).	General Quality of Effluent, as described by Dr. McGowan.	Units of Purification.
			Gallons.	Parts per 100,000	Parts per 100,000		
Chorley	Chemical precipitation and percolating filters	Very fine to coarse	500	50	0·9	Good	24,550§
Rochdale	Septic tank and percolating filters	Coarse	141	83	4·4	Good	11,125
Dorking (Experimental Works)	Chemical precipitation and percolating filters	,,	211	55·3	3·9	Very fair	10,845
Kingston-upon-Thames	Chemical precipitation and single contact beds	Medium to coarse	250	51	7·7	Good	10,825
York	Septic tank and percolating filters	Coarse	150	58	−3·5‡	Good, apart from solids	9,225
Accrington	,, ,, ,,	,,	140	94	28·4	Good, apart from solids	9,184
Dorking (Experimental Works)	Chemical precipitation and percolating filters	,,	175	53·5	3·5	Very fair	9,065
,,	Settlement tank and percolating filters	,,	120	80·1	8·8	Fair	8,556
,,	Septic tank and percolating filter	,,	120	81·6	11·2	Moderate	8,448
Normanton	Chemical precipitation and percolating filters	Very fine to coarse	98	92	10·0	Very fair	8,036
Birmingham	Septic tank and percolating filter	Medium to coarse	82½	113	20·2	Fair to good	7,656
Hampton	Triple contact beds	1st bed, coarse; 2nd bed, medium; 3rd bed, fine	43	172	−3·7‡	Good	7,555
Halton	Settlement tanks and double contact beds	Coarse	106	80	10·8	Indifferent	7,335
Hartley Wintney	Septic tank and percolating filter	Medium to fine	73	108	8·5	Moderate	7,264
Manchester	,, ,, ,,	Medium	77	106	15·0	Rather poor	7,007
Huddersfield	Septic tank and single contact beds	Coarse	110	77·1	16·4	Good, apart from solids	6,897
Dorking (Experimental Works)	Chemical precipitation and percolating filter	,,	120	68·8	18·1	Not very good	6,084
Hartley Wintney	Septic tanks and single contact beds	Medium to fine	73	108	27·3	Poor	5,871
Huddersfield	Septic tank and double contact beds	1st, coarse; 2nd, medium	76	77·1	3·1	Fair to good	5,624
Calverley	Chemical precipitation and single contact beds	Coarse to fine	60	124	33·2	Poor	5,448
Rochdale	Chemical precipitation and percolating filter	Coarse	157	39	5·7	Good, apart from solids	5,228
Guildford	Septic tank and percolating filter	,,	50	109·2	4·8	Good	5,220

Heywood	Chemical precipitation and single contact beds	Very fine to coarse	173	40·2	11·0	Evidently not very good	5,052
Caterham	Septic tank and percloating filter	Medium to coarse	31	161	14·0	Fair	4,557
Withnell	Chemical precipitation and percolating filters	Very fine to coarse	63½	81	9·3	Very fair	4,553
Andover	Septic tank and single contact bed	Medium to fine	115	90	50·5	Poor	4,543
Horfield	Chemical precipitation and percolating filter	Coarse	151	36	6·0	Very fair to good	4,530
Leeds	Percolating filter (Leeds filter)	Very coarse	52	123	36·7	Fair	4,488
,,	,, ,, (Ducat)	Medium	25	172·6	2·3	Very good	4,373
,,	Septic tank and percolating filter	Coarse	63	75·8	7·2	Good, apart from solids	4,322
,,	Septic tank and double contact bed	1st, fine to medium; 2nd, medium	45	92·4	– 3·1‡	Good	4,298
Guildford	Septic tank and percolating filter	Coarse	50	90·3	4·8	Good	4,275
Leeds	Double contact beds	1st, coarse; 2nd, medium	32	127	5·2	Moderate	3,998
Hendon	Percolating filter (Ducat)	Medium	40	107	7·9	Good, when settled	3,964
Maidstone	Double contact beds	1st beds, coarse; 2nd beds, fine	23·7	164	4·7	Moderate to fair	3,775
Exeter (Main Works)	Septic tank and single contact beds	Medium to coarse	55	99	31·2	Poor	3,729
Oswestry	Double contact beds	1st, medium to coarse; 2nd, medium	41	91	4·7	Fair	3,538
Sheffield	,, ,, ,,	Medium to fine	60	57·6	5·1	Good	3,150
Burnley	Septic tank and double contact beds	1st, coarse; 2nd, fine	40	74·1	– 1·0‡	Good	3,004
Withnell	Double contact beds	1st, coarse; 2nd, medium	18·2	174	25·3	Not satisfactory	2,706
Exeter (St. Leonard's)	Septic tank and single contact beds	Medium to fine	75	39	3·0	Fair	2,700
Guildford	Septic tank and double contact beds	1st, medium to coarse; 2nd, medium to fine	22·7	125	6·2	Moderate	2,697
Leeds	Settlement tank and percolating filter	Coarse	63	59·7	16·9	Good, apart from solids	2,696
,,	Chemical precipitation and percolating filter	,,	50	51·8	– 0·4‡	Good to very good	2,610
Oldham	Single contact beds	Medium to fine	73	51·1	15·7	Moderate	2,584
Little Drayton	Settlement tank and percolating filter	Medium	15·2	165	6·4	Good to fair	2,411
Withnell	Chemical precipitation and percolating filter	Very fine to coarse	63½	29·8	0	Good	1,892
Clifton	Settlement tank and percolating filter	,, ,,	15·6	123	5·8	Good to fair	1,828
Slaithwaite	Septic tank and single contact bed	Medium to coarse	62	35·6	6·3	Indifferent	1,817
Prestolee	Septic tank and percolating filter	Fine to coarse	46	22	0	*Very* good	1,012

* The strength of the liquor and filter effluent is expressed by the amount of oxygen required for the complete oxidization of its ammonia and organic matter. ‡ The minus sign which is placed against the figure representing the strength of certain effluents indicates that the oxygen present, in the form of nitrate, was, to the extent of the figure against which it is placed, more than sufficient to oxidize the organic matter in the effluent. § This figure is based on a volume of 500 gallons per cube yard per day—the actual rate at the time when the average samples were drawn. Probably about 400 gallons per cube yard per day is as much as the filters could continuously treat, and, on this basis, the number of units of purification would be rather under 20,000.

Accrington Experiments.

180. For the purpose of making an accurate comparison of the working power of contact beds and percolating filters treating the same sewage liquor, and also for comparing the treatment of strong and dilute tank liquors on each form of filter, we constructed an experimental plant at the Accrington Sewage Works.

The plant consisted of two pairs of exactly similar contact beds, 3 feet deep, and two exactly similar percolating filters, of rather coarse material, each 6 feet deep.

The cubic contents of each percolating filter was equal to that of each pair of contact beds.

The details of these experiments are set out in a Memorandum by Dr. McGowan and Mr. Colin Frye, contained in Appendix IV.

The experiments were carried out with great care, both on the spot and in the laboratory, and the results may be regarded as quantitative comparative results, from which we think useful generalisations may be drawn.

For the construction of the filters we are greatly indebted to Mr. W. J. Newton, the Surveyor to the Accrington and Church Sewage Board, while Mr. J. Boothman, the Chemist in charge at the outfall works, has controlled their daily working. The delicate adjustment of the dilutions of the tank liquor, upon which the whole value of the experiments depends, has been carried out by Mr. Boothman with the greatest care and skill, and with consistent success.

The liquor treated throughout has been the Accrington septic tank liquor, either by itself or diluted with water.

Our intention had been to treat at the same rate on the percolating filters and the contact beds, but as will be seen, it was not practicable to do this.

181. There were five experiments in all, as follows :—

Experiment I.—Comparative treatment on percolating filters and contact beds of (*a*) 100 gallons per cube yard per 24 hours of septic tank liquor and (*b*) 100 gallons of septic tank liquor + 100 gallons of water = 200 gallons of weak liquor.

The *actual average* rates of filtration on the two pairs of contact beds were 72·2 and 148·8 gallons per cube yard per day, respectively, the beds treating strong liquor being filled twice a day and those treating weak liquor four times a day. Broadly speaking, therefore, the contact beds only treated in this experiment three-fourths of the volumes treated by the percolating filters. This was owing partly to the original water capacity being less than 100 gallons per cube yard, and partly to their gradual loss of capacity. At the commencement of the experiment two fillings per day on the pair of contact beds treating strong liquor were equivalent to 90 gallons per cube yard, and four fillings per day on the pair treating weak liquor were equivalent to 179 gallons.

Duration of experiment :—May 5th, 1905, to June 30th, 1906.

Experiment II.—Comparative treatment on percolating filters and contact beds of (*a*) 100 gallons per cube yard per 24 hours of septic tank liquor and (*b*) of 50 gallons of septic tank liquor + 50 gallons of water = 100 gallons of weak liquor.

The *actual average* rates on the contact beds were 51·6 and 57·9 gallons per cube yard per day, respectively,

Duration of experiment : July 2nd, 1906, to March 23rd, 1907.

Experiment III.—Comparative treatment on percolating filters *alone* of (*a*) 125 gallons per cube yard per 24 hours of septic tank liquor and (*b*) 125 gallons of septic tank liquor + 125 gallons of water = 250 gallons of weak liquor.

Duration of experiment :—April 8th to June 7th, 1907.

Experiment IV.—Comparative treatment on percolating filters alone of (*a*) 200 gallons per cube yard per 24 hours of septic tank liquor ; and (*b*) 200 gallons of septic tank liquor+200 gallons of water=400 gallons of weak liquor.

Duration of experiment :—June 10th to October 26th, 1907.

Experiment V.—Comparative treatment on percolating filters alone of (*a*) 250 gallons per cube yard per 24 hours of septic tank liquor ; and (*b*) 250 gallons of septic tank liquor +250 gallons of water=500 gallons of weak liquor.

Duration of experiment :—October 28th, 1907, to June 18th, 1908.

The main object of these last three experiments, besides the further comparison between the purification of the two liquors, was to see how much these filters can actually treat, with the production of a good effluent.

The following is a general summary of the results of these experiments :—

182. *Accrington Experiment I.*—The percolating filters of coarse material effected practically the same amount of purification, whether they were treating 100 gallons per cube yard of undiluted septic tank liquor, or 200 gallons per cube yard of a liquor of half the strength, the total organic impurity going on to the filters being the same in both cases.

The primary contact bed, when the pair of beds were treating about 150 gallons of weak liquor per cube yard per day, gave rather better results than the primary bed of the pair treating strong liquor at half this rate, and the same is true, in each case, of the secondary beds. So long, therefore, as care is taken to avoid water-logging, *i.e.*, to give the beds sufficient time to drain and aerate, it is rather easier to treat upon contact beds two volumes of weak liquor than one volume of strong liquor.

During the fourteen months over which this experiment extended, the percolating filters treating strong liquor did one and a half times as much work as the contact beds treating strong liquor, while the percolating filters treating weak liquor did one and a third times as much work as the contact beds treating weak liquor.

The units* of purification were as follows :—

	Units of Purification per cube yard.
Percolating filter treating strong tank liquor - -	7,310
Double contact beds treating strong tank liquor -	5,011
Percolating filter treating weak tank liquor - -	7,678
Double contact beds treating weak tank liquor - -	5,803

As regards the quality of the two strong liquor effluents, *suspended solids included*, the results were slightly in favour of the percolating filter effluent, which still required 12 parts of oxygen per 100,000 for its complete oxidation, while the contact bed effluent required 16 parts. If we *eliminate the solids* in both cases, the oxidizability of the liquid alone would be approximately represented by 2 parts of oxygen in the case of the percolating filter effluent, and 8 parts in the case of the contact bed effluent. This superiority of the percolating filter effluent, so far as lesser oxidizability is concerned, was partly due to the fact that it contained 2·4 parts of nitric (plus nitrous) nitrogen, as against 1 part in the contact bed effluent ; but even apart from this, it was rather the better, the actual oxidizable matter left in the liquid being equivalent to about 8·5 parts of oxygen, while that in the contact bed effluent was equivalent to about 10 parts.

In the case of the two weak liquor effluents, suspended solids included, the results were in favour of the double contact bed effluent, which only required 4 parts of oxygen for its complete oxidation, as against 9·5 parts for the percolating filter effluent. If we eliminate the solids, there was practically no difference in the quality of the two effluents, both of them being well oxidized. If both solids and nitrate are eliminated, the double contact bed effluent is again rather the better, with an oxidizability figure of 4, as against 6·5 for the percolating filter effluent.

The above figures may be tabulated as follows :—

	Effluents from Strong Tank Liquor.		Effluents from Weak Tank Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
† Oxidizability of whole effluent, including solids and giving credit for nitrate - - -	*Parts of* 12	*oxygen per* 16	100,000 *parts* 9·5	*of effluent.* 4·0
Oxidizability of effluent, without its suspended solids, and giving credit for nitrate - -	2	8	2·0	2·0 ap.
Oxidizability of effluent, without solids, and giving no credit for nitrate - - - - -	8·5	10	6·5	4·0

* The units of purification are calculated on the basis indicated on page 107 of this Report.

† Oxidizability calculated on the formula suggested by Dr. McGowan (*see* paragraph 179, page 107).

The quality of the effluents *without their suspended solids*, as regards taking up of dissolved oxygen in 24 hours and incubation, is shown by the following figures:—

Parts per 100,000.

	Effluents from Strong Tank Liquor.		Effluents from Weak Tank Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
Dissolved oxygen taken up from water in 24 hours at about 18° C. (65° F.)	0·30 (22) 0·37 (12)	0·61 (11)	0·28 (21) 0·30 (11)	0·31 (10)
Incubation (by smell)	All passed (25).	All passed (11).	All passed (21).	All passed (10).

Figures in brackets represent number of estimations.

183. *Accrington Experiment II.*—In the comparative treatment, *upon the percolating filters of coarse material*, of 100 gallons of strong and 100 gallons of weak tank liquor, respectively, nothing was gained in purity of effluent by giving the filter treating the weak liquor only half the work to do; this filter was merely working much under its real power.

It was noteworthy that in Experiments I. and II. the actual efficiency of the contact beds (treating both strong and weak tank liquor), as regards work done per cube yard, remained the same throughout. In both experiments about two-thirds of the impurity of the septic tank liquor was removed by the primary bed, whether strong or weak liquor was being treated.

In Experiment II., which lasted for eight months, the percolating filter treating 100 gallons per cube yard of strong liquor did more than twice as much actual work as the double contact beds treating 51·6 gallons with two fillings per day; the reason for this increasing difference in work done, as compared with Experiment I., was the gradual loss of capacity in the contact beds.

The units of purification in Experiment II. were as follows:—

	Units of Purification per cube yard.
Percolating filter treating strong tank liquor	8,440
Double contact beds treating strong tank liquor	3,576
Percolating filter treating weak tank liquor	4,120
Double contact beds treating weak tank liquor	2,200

The quality of the effluents was as follows:—

	Effluents from Strong Tank Liquor.		Effluents from Weak Tank Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
	Parts of oxygen per 100,000 *parts of effluent.*			
Oxidizability of whole effluent including solids, and giving credit for nitrate	−3·2	14·0	−0·7	4·2
Oxidizability of effluent, without its suspended solids and giving credit for nitrate	−6·2	5·8	−3·3	0·2
Oxidizability of effluent, without solids and giving no credit for nitrate	3·6	7·7	2·4	3·2

NOTE.—The minus sign indicates that the oxygen present, in the form of nitrate, was, to the extent of the figure against which it is placed, more than sufficient to oxidize the organic matter in the effluent.

The quality of the effluents—*without their suspended solids*—as regards taking up of dissolved oxygen and incubation, is shown by the following figures :—

	Effluents from Strong Tank Liquor.		Effluents from Weak Tank Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
		Parts per 100,000.		
Dissolved oxygen taken up from water in 24 hours at about 18° C.	0·03 (4)	0·12 (4)	0·07 (4)	0·10 (4)
Dissolved oxygen taken up from water in 5 or 6 days	0·43 (3)	1·70 (3)	0·33 (4)	1·0 ap. (3)
Incubation (by smell)	All passed (8)	All passed (8)	All passed (8)	All passed (8)

The capacities of the contact beds were as follows :—

	At beginning of Experiment, July 2nd, 1906.	At end of Experiment, February 18th, 1907.	Loss of capacity in Gallons.	Percentage loss of water capacity.
	gallons.	gallons.		
Primary bed treating strong tank liquor	735	640	95	8 per cent.
Secondary bed treating strong tank liquor	1,030	970	60	6 „
Primary bed treating weak tank liquor	780	750	30	3 „
Secondary bed treating weak tank liquor	950	890	60	6 „

As already stated, the actual volumes of liquid treated per cube yard per twenty-four hours throughout Experiment II. were :—

Percolating filter treating strong tank liquor - 100 gallons.
Double contact beds treating strong tank liquor - 51·6 „
Percolating filter treating weak tank liquor - 100 „
Double contact beds treating weak tank liquor - 57·9 „

The contact beds thus treated only about half as much liquor, in both cases, as the percolating filters.

184. *Accrington Experiment III.*—In this experiment, which lasted from April 8th to June 7th, 1907, the percolating filter treating strong liquor received 125 gallons per cube yard per day and that receiving weak liquor 250 gallons per cube yard per day. It was thus similar to Experiment I, but with an increased dose in the case of both filters, the object being to see how much the filters could actually treat with efficiency. Owing to the wet season, however, the strength of the liquors in this last experiment was less than in Experiments I and II, thus :—

	Calculated Strength.	Suspended Solids.
Strong tank liquor	73·2	20·1
Weak tank liquor	40·7	10·3

The suspended solids in the filter effluents were rather high, on account of the "spring out-flush." *

The purification obtained was as follows :—

	Units of Purification per cube yard.
Percolating filter treating strong tank liquor	8,050
Percolating filter treating weak tank liquor	9,225

* As is now well known, large quantities of suspended solids usually come out in the effluent from a percolating filter of coarse material in the late spring, with the advent of the warmer weather. This appears to be due to the development of worms, larvæ, etc., in the interior of the filter at this time. The same thing has been observed, though in lesser degree, in the case of percolating filters of fine material and also contact beds.

The quality of the two effluents is shown by the following figures :—

	Effluents from Strong Tank Liquor.	Effluents from Weak Tank Liquor.
	Parts of oxygen per 100,000 parts of effluent.	
Oxidizability of whole effluent, including solids and giving credit for nitrate.	8·8	3·8
Oxidizability of effluent, without its suspended solids and giving credit for nitrate.	– 2·2*	– 1·4*
Oxidizability of effluent, without solids and giving no credit for nitrate.	4·8	2·7

The quality of the effluents—*without their suspended solids*, as regards taking up of dissolved oxygen and incubation—is shown by the following figures :—

	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
Dissolved oxygen taken up from water in 5 days at 18° C. -	0·62 (5)	0·84 (5)
Incubation (by smell) - - - - - - - - -	All passed (5)	All passed (5)

Both effluents were therefore very good, and, apart from their suspended solids, there was practically nothing to choose between them. It will be noted that the filter treating weak liquor was receiving a liquor a little more than half as strong as the other (calculated strength—40·7, as against 73·2 for the strong liquor).

Owing to the strong liquor being less concentrated in this experiment than in the two preceding ones, the actual work done on the filter treating strong liquor was only 8,050 units per cube yard per 24 hours, but in the case of the filter treating weak liquor it was 9,225 units.

185. *Accrington Experiment IV.*—In this experiment, which lasted from June 10th to October 26th, 1907, the percolating filter treating strong liquor received 200 gallons per cube yard per day, and that receiving weak liquor 400 gallons per cube yard per day. It was thus similar to Experiments I. and III., but with a further increased dose in the case of both filters. The calculated strengths of the tank liquors in this experiment were almost the same as in the preceding one, but the suspended solids were less in amount, thus :—

	Calculated Strength.	Suspended Solids.
Strong tank liquor - - - - - - - - - -	74·1	13·5
Weak tank liquor - - - - - - - - - -	39·6	6·3

The weak liquor filter was again treating a liquor which was *rather more* than half as strong as the other.

The purification obtained was as follows :—

	Units of Purification per Cube Yard.
Percolating filter treating strong tank liquor - - - -	14,300
Percolating filter treating weak tank liquor - - - -	15,160

The quality of the two effluents is shown by the following figures :—

	Effluents from Strong Tank Liquor.	Effluents from Weak Tank Liquor.
	Parts of oxygen per 100,000 parts of effluent.	
Oxidizability of whole effluent, including solids and giving credit for nitrate - - - - - - - - - -	2·6	1·7
Oxidizability of effluent, without its suspended solids and giving credit for nitrate - - - - - - - - -	– 3·8*	– 3·1*
Oxidizability of effluent, without solids and giving no credit for nitrate - - - - - - - - - -	4·4	2·3

* The minus sign indicates that the oxygen present, in the form of nitrate, was, to the extent of the figure against which it is placed, more than sufficient to oxidize the organic matter in the effluent.

The quality of the effluents—*without their suspended solids*, as regards taking up of dissolved oxygen and incubation—is shown by the following figures :—

	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
Dissolved oxygen taken up from water in five days at 18°C. -	0·56 (9)	0·49 (9)
Incubation (by smell) - - - - - - - - - -	All passed (9)	All passed (9)

Here, again, both effluents were well oxidized and good, and there was little to choose between them. If anything, they were rather better oxidized than the corresponding effluents in Experiment III. (notwithstanding the lesser volumes treated in that case), as judged by the dissolved oxygen taken up by the paper-filtered effluents in five days. This was probably due to the fact that more of the warm summer months were included in Experiment IV.; and that the spring out-flush of solids took place during Experiment III.

The work done on the filter treating strong liquor was 14,300 units, and on the filter treating weak liquor 15,160 units.

186. *Accrington Experiment V.*—In this final experiment, which lasted from October 28th, 1907, to June 18th, 1908, the percolating filter treating strong liquor received 250 gallons per cube yard per day, and that receiving weak liquor 500 gallons per cube yard per day. The calculated strengths of the liquors treated were a little less than in Experiment IV., though suspended solids were present in rather larger amount, thus :—

	Calculated Strength.	Suspended Solids.
Strong tank liquor - - - - - - - - - -	69·4	14·4
Weak tank liquor - - - - - - - - - -	37·0	7·4

As before, the weak liquor filter was treating a liquor which was fully half as strong as the other.

The purification obtained was as follows :—

	Units of Purification per cube yard.
Percolating filter treating strong tank liquor - - - - -	12,425
Percolating filter treating weak tank liquor - - - - -	14,600

The quality of the two effluents is shown by the following figures :—

	Effluents from Strong Tank Liquor.	Effluents from Weak Tank Liquor.
	Parts of oxygen per 100,000 parts of effluent.	
Oxidizability of whole effluent, including solids and giving credit for nitrate - - - - - - - -	19·7	7·8
Oxidizability of effluent, without its suspended solids and giving credit for nitrate - - - - - -	7·1	2·2
Oxidizability of effluent, without solids and giving no credit for nitrate - - - - - - - - - -	10·8	5·0

The quality of the effluents—*without their suspended solids*, as regards taking up of dissolved oxygen and incubation—is shown by the following figures :—

	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
Dissolved oxygen taken up from water in five days at 18°C. -	2·31 (13)	1·16 (13)
Incubation (by smell) - - - - - - - - - -	{ 11 passed / 2 failed (13) }	All passed (13)

The effluents in Experiment V. thus show a marked falling off in quality as compared with those in Experiments IV. and III. Leaving suspended solids out of account, the weak liquor effluent is distinctly better, relatively, than the effluent from the strong liquor. It will be noted, however, that even in this last experiment, after filtration through paper, only two of the thirteen strong liquor effluents failed on incubation, while all thirteen weak liquor effluents passed that test. The latter effluents might be described as fairly good, but the strong liquor effluents as rather poor. The spring outflush of solids again took place during this experiment, which—it must be borne in mind—was carried out for the most part in the coldest months of the year.

The work done on the filter treating strong liquor was 12,425 units and on the filter treating weak liquor 14,600 units.

It was evident, from the appearance of the filters during the progress of Experiment V., that they were being overtaxed, especially the strong liquor filter. The concrete at the base of the filters gradually became blackened and covered, more or less, with grey fungus, while at times the effluents smelt slightly of sewage.

187. Reviewing shortly the foregoing five experiments, we think that they may be taken to show that percolating filters of coarse material, 6 feet deep, can treat a strong septic tank liquor (strength 73 to 85) at a rate of 100 to 125 gallons per cube yard per day, or a liquor of half this strength at the rate of 200 to 250 gallons, giving from 8,000 to 9,000 units of purification, and producing at the same time a good effluent (apart from suspended solids).

Under favourable conditions of summer weather, a strong septic tank liquor (strength 74) can be treated at a rate up to 200 gallons per cube yard per day, or a liquor of half this strength at a rate up to 400 gallons per day, with from 14,000 to 15,000 units of purification and the production of a good effluent. This, we think, is probably the maximum work which can be expected from percolating filters of coarse material treating ordinary septic tank liquor at a regular rate of flow.

As regards the question whether it is easier to treat upon percolating filters of coarse material one volume of strong septic liquor or two volumes of weak, the organic impurity being the same in both cases, there is little difference either in the actual work done by the filters or in the quality of the effluents, at rates of working up to 200 and 400 gallons per cube yard per day. If any distinction is to be drawn, the advantage lies with the filter treating the weaker liquor, no doubt because the natural aeration of the extra volume of liquid rather more than counterbalances the quicker rate of flow through the filter.

Apart from complications arising from the presence of large quantities of suspended solids (*cf.* pp. 48 *et. seq.*), we think that the above statement with regard to the purification of strong and weak septic-tank liquors may be taken to apply also to settled sewage and precipitation liquor.

Double contact beds will, during their first year of work, at the rate of two fillings per day, treat 70 gallons of strong or 150 gallons of weak tank liquor per cube yard per day, with 5,000 to 6,000 units of purification for the first year. Their working power will, however, gradually fall off as the beds lose capacity. Here, again, it is rather easier to treat two volumes of weak than one volume of strong liquor.

It is clear from these experiments that, other things being equal, a greater purification per cube yard, as measured by the actual *amount* of oxygen used up, is effected when the final product is an *imperfectly* oxidized effluent. The indications are that, unit for unit, the first or carbon stage of the oxidation is, under the conditions of filtration, easier, or at least quicker, and therefore presumably requires less expenditure of energy than the second or nitrification stage. We may perhaps be able to make some further experiments with these filters, to clear up this point.

At the end of this section (*see* p. 121) we print in a summarized form tables of the results from a large number of places, most of which have been under our own observation.

General Conclusions as to the Working Power of Different Types of Filter.

188.—*Treatment of Crude or Partially Settled Sewage upon Double Contact Beds.*

The volume of sewage which can be treated by double contact, so as to give a fair or good effluent, varies almost inversely as the "strength," *e.g.*, 24 gallons per cube yard per day of sewage with a strength of 164, or 58 gallons of sewage with a strength of 60. During the "economic life" of the beds, an average of 3,000 to 4,000 units of purification per cube yard of filter per day may be looked for in the treatment of crude or settled sewage upon primary beds of coarse material and secondary beds of fine material, an effluent of fair to good quality being produced.

Treatment of Crude or Partially Settled Sewage on Percolating Filters.

Broadly speaking, the volume of sewage which can be treated upon percolating filters, with the production of a good effluent, depends mainly upon its strength, especially if no complications ensue through the choking of the filter and if the filter is working up to its full power. Twenty to 25 gallons per cube yard per day of a sewage having a strength of about 170, or 60 gallons of sewage with a strength of 60, can be successfully dealt with upon filters of medium to coarse material, 2,500 to 3,500 units of purification being obtained. When the sewage is *well settled*, about 100 to 120 gallons of such sewage with a strength of about 80, can be filtered per cube yard per day, and 7,000 to 8,000 units of purification, or probably even more than this,† obtained. In this case, therefore, the process is comparable with the treatment of septic liquor upon percolation filters.

Treatment of Septic Tank Liquor on Single Contact Beds.

The volume of septic tank liquor which can be treated by single contact varies almost inversely as the strength of the liquor. Single beds of medium to coarse or medium to fine material, may be expected to give from 3,000 to 4,500 units of purification, when dealing with either strong or weak liquors. If the tank liquor is a weak one, and if the material of the bed is fine, this purification will be sufficient to yield a good or fairly good effluent, but not otherwise. A weak liquor, of strength 30 to 50, and containing up to 6 or 8 parts of suspended solids, can in this way be successfully treated at the rate of 100 to 150 gallons per cube yard per day. As a rule, however, septic tank liquors are too strong to allow of one contact being sufficient to give a good effluent.

Treatment of Septic Tank Liquor on Double Contact Beds.

The volume of septic tank liquor which can be treated by double contact varies almost inversely as the strength. Where the *primary* beds are of medium to fine material a strong liquor of strength 90 may be treated by double contact at the rate of 50 gallons per cube yard per day; a liquor of strength 70 at the rate of 70 gallons; and a weak liquor of strength 40 at the rate of 100 gallons. From 3,500 to 4,500 units of purification may be expected here, with the production of good effluents.

Treatment of Septic Tank Liquor on Percolating Filters.

The volume of septic tank liquor which can be treated upon percolating filters varies more or less inversely as the strength. A percolating filter of coarse or of medium to coarse material, and from 6 to 9 feet in depth, may be expected to give from 7,000 to

† *Cf.* Appendix IV., Report to the Commission on the Dorking Experimental Installation, by E. H. Richards (1907).

11,000 units of purification when treating either strong or weak tank liquors, and to yield good effluents. This would correspond to 80 gallons per cube yard of a strong liquor of strength 113, or 150 gallons of a weak liquor of strength 58. The less coarse the material, provided that it can allow the free passage of effluent suspended solids through it, the greater is the relative purification per cube yard.

Treatment of Precipitation Liquor on Single Contact Beds.

Our data with regard to this process are rather few, but they indicate clearly that—as in the case of settled sewage and septic tank liquor—single contact of precipitation liquor from strong sewages is not sufficient to produce a good effluent. The better clarified the liquor, the more of it can be treated. The very well clarified liquor at Kingston-on-Thames, with a strength of about 50, was treated for over six years upon an experimental coke bed of medium to coarse material, 3 feet deep, at a rate of 250 gallons per cube yard per day (four fillings), giving 10,800 units of purification and producing a fair to good effluent. A more dilute tank liquor, equally well clarified, might be treated in even larger volume than this, so far as the " strength " was concerned, but it is doubtful whether more than four fillings per day would be practicable on a large scale for any length of time.

Treatment of Precipitation Liquor on Double Contact Beds.

We have had no actual experience of this process, which would be applicable to precipitation liquors from strong sewages. We should not expect, however, to obtain such a high figure for units of purification as in the treatment of medium or weak liquor by single contact. Probably about 6,000 to 7,000 units would be the maximum obtainable. This would correspond to about two to two and-a-half fillings per day of a liquor of strength 100 or about three to three and-a-half fillings of a liquor of strength 75.

Treatment of Precipitation Liquor on Percolating Filters.

In this case it cannot be said that the volume of precipitation liquor treated per cube yard of filter at the different places under observation varied inversely as the strength. The main reason for this is that suspended solids can be reduced in most precipitation liquors to a very low figure, in which case very fine material may be used for the filtration of large volumes. At the places which were under observation the filtering material varied greatly in size and the liquors contained very different quantities of suspended solids. Nevertheless with material of a given size, strength and volume would, no doubt, bear an inverse relation to one another. From the results obtained with percolating filters, of coarse and fine material, respectively, we have arrived at the following broad conclusions :—

(*a*) The volume of precipitation liquor which can be treated upon filters of *coarse* material depends mainly upon the strength of the liquor.

(*b*) The volume which can be treated upon filters of *fine* material depends not merely upon the strength, but also to a marked extent upon the degree of clarification of the liquor.

Upon deep filters of coarse material, about 150 gallons of precipitation liquor of about average strength (strength 50 to 60) or 200 to 250 gallons of weak liquor (strength 30 to 40) can be treated per cube yard per day, yielding up to about 8,000 units of purification, and producing a good effluent. In the case of very strong liquors the volume would probably have to be *more than* proportionately reduced.

Upon shallow filters of fine material a *clear* liquor with a strength of 50 can be treated at the rate of 300 to 400 gallons per cube yard per day, giving about 18,000 units of purification, and producing a very fair to good effluent. It has to be borne in mind, however, that filters of very fine material working at this rate have to be constantly washed and scraped. About 500 gallons per cube yard per day would probably be the largest volume of any liquor, however weak, that could be treated on such filters regularly, day by day.

The rates of treatment which are given in the foregoing paragraphs could generally be doubled in times of storm.

Summary.

189. The following tables gives an *approximate* idea of the purification which can be effected by different kinds of filter treating different liquors, so as to produce a fair to good effluent :—

	Units of Purification per cube yard :—
Crude or partially settled sewage treated on double contact beds	3,000 to 4,000
Crude or partially settled sewage treated on percolating filters	2,500 to 3,500
Well settled sewage treated on percolating filters	7,000 to 8,000, and probably up to 11,000
Septic tank liquor treated on single contact beds	3,000 to 4,500
Septic tank liquor treated on double contact beds	3,500 to 4,500
Septic tank liquor treated on percolating filters	7,000 to 11,000
Precipitation liquor treated on single contact beds	Up to 11,000
Precipitation liquor treated on double contact beds	*Probably* up to 6,000 to 7,000
Precipitation liquor treated on percolating filters :—	
(*a*) Filters of coarse material	Up to about 8,000
(*b*) Filters of fine material	Up to about 18,000

General Summary as to Contact Beds and Percolating Filters.

190. (1)—The amount of sewage which can be purified per cube yard of contact bed or percolating filter varies—within practical limits—nearly inversely as the strength of the liquor treated. This statement is based on the assumption that the size of the material of which the filter is composed is, in each case, suitable to the character of the liquor treated, and that the material is arranged at the proper depth to secure maximum efficiency (*see* Paragraph 153, p. 87).

(2) Taking into account the gradual loss of capacity of contact beds, a cubic yard of material arranged in the form of a percolating filter will generally treat satisfactorily nearly twice as much tank liquor as a cubic yard of material in a contact bed.

(3) In the case of sewage containing substances which have an inhibitory effect upon the activity of micro-organisms, the working power per cube yard of filter of either type may be more nearly equal. This point, however, is not clearly established.

(4) Percolating filters are better adapted to variations of flow than contact beds.

(5) The effluents from percolating filters are usually much better aerated than the effluents from contact beds, and apart from suspended solids, are of a more uniform character. On emptying a contact bed, the first flush is usually much more impure than the average effluent from the bed.

(6) The risk of nuisance from smell is greater with percolating filters than with contact beds.

(7) It is also found that with percolating filters, there is nuisance from flies, especially with filters constructed of coarse material. In the warmer months of the year, such filters swarm with members of the *Psychodidae*, which, though appearing to breed and develop in the filters, may usually be seen in large numbers on the walls of houses and buildings close to or on the works. At Accrington and Dorking a small midge-like fly with a dark body and striped wings has appeared and causes inconvenience to the men by its bite, which gives rise to local irritation.

TABLES OF ANALYTICAL RESULTS OBTAINED: (*a*) AT THE DIFFERENT SEWAGE WORKS WHICH HAVE BEEN UNDER OBSERVATION BY OUR OWN OFFICERS; (*b*) BY THE AUTHORITIES AT THE SEWAGE WORKS OF BIRMINGHAM, BURNLEY, HEYWOOD, HUDDERSFIELD, LEEDS, MANCHESTER, OLDHAM, AND SHEFFIELD.

Prefatory Note to Tables.

191. The figures of analysis given for crude and settled sewage, septic tank liquor, and precipitation liquor, refer to the *hourly* sets of samples only in the case of the works which have been under observation by our own officers, these hourly sets representing as far as possible the dry weather flow. For purposes of comparison, we have given the average figures for the *hourly* sets of effluent samples (*i.e.*, dry weather samples), and the average figures for the ordinary *chance* samples of effluent. There were, as a rule, a fair number of such chance effluents examined from each place, and the figures may generally be looked upon as representing roughly the average of the effluents obtained in all weathers. In the case of the other places (Leeds, Manchester, etc.) the figures given for the sewages, tank liquors, and effluents are the averages of a very large number of *chance* samples. These latter figures were furnished by the authorities of the various sewage works mentioned, and they are printed in italics to distinguish them from our own figures.

The figures for "oxygen absorbed in four hours" given in italics were obtained with weak permanganate, and therefore require to be multiplied by 1·6, in order to make them fairly comparable with our own *four hours*' figures, which were obtained with strong permanganate.

With regard to the bacteriological notes, wherever possible, the figures given refer to the number of B. Coli (or Coli-like microbes) per c.c. In the few cases where this test was not applied, or where the records were very few in number, approximate figures are given, based upon the results obtained by the use of one or more presumptive tests for B. Coli. The results frequently varied so much that the figures can only be taken as being roughly approximate; bacteriological results obtained by the decimal method of dilution do not lend themselves readily to expression in the form of averages. Further, a good deal of latitude has been exercised in the way of pitting high results against low results and ignoring exceptional ones. We think, therefore, that the bacteriological figures given in the following tables should be read in the light of the detailed tables which are incorporated in the text of the separate reports, printed in Appendix III.

TABLE I.—ANALYSES OF CRUDE SEWAGE.

No.	Place.	Population	System of Sewerage.	Dry weather flow of Sewage (gallons).	Nature of Sewage.	Analysis of Sewage. Parts per 100,000.				B. Coli per c.c.	Preliminary Grit Settlement.	Remarks.
						Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.			
1	Hampton -	6,500	Separate	180,000	Strong domestic	9·40	1·38	17·82	48·5	At least 100,000.	Partial settlement on surface of primary beds.	
2	Leeds - -	450,000	Combined	15,500,000	Trade sewage	*3·28*	*1·26*	*14·10*	*85·0* D.	About 100,000.	Partial settlement	Experimental processes. Fixed quantity treated daily; compare D with Ducat filter effluent, C with contact bed effluent, and L with "Leeds" filter effluent.
						2·30	*0·65*	*10·27*	*53·3* L.			
						1·54	*0·85*	*10·80*	*52·5* C.			
3	Maidstone -	34,000	Partially separate.	1,500,000	Domestic, with much brewery and tannery waste.	3·51	1·52	21·03	34·8	At least 100,000.	Partial settlement in pump well.	Experimental process. Fixed quantity treated daily.
4	Newton -	9,000	Combined	145,000	Domestic (mainly slop water).	4.30*	0·86*	12·32	30·6	At least 100,000.	Slight settlement in distributing troughs.	
5	Withnell -	1,650	Partially separate.	15,000	Very strong domestic	5·35	1·23	21·19	33·9	At least 100,000.	Partial settlement in grit chamber.	Experimental process. Fixed quantity treated daily.

NOTE—The figures of analysis given in ordinary type are, as a rule, averages of three sets of twenty-four hourly samples, drawn in dry weather, according to rate of flow. The figures of analysis given in italics are, as a rule, averages of a large number of chance samples, drawn in all weathers. All figures for "Oxygen absorbed in four hours" given in italics, having been obtained with "weak" permanganate, must be multiplied by 1·6 to compare approximately with the figures for "Oxygen absorbed in four hours" given in ordinary type, the latter having been obtained with "strong" permanganate.

* These numbers are inferred; they will be nearly right.

TABLE II.—SETTLEMENT OF SEWAGE

No.	Place.	Population.	System of Sewerage.	Dry weather flow of Sewage (gallons).	Nature of Sewage.	Analysis of Sewage. Parts per 100,000. Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.	B. Coli per c.c.
7	Clifton - -	2,000	Partially separate.	22,000	Strong slop-water domestic.	3·78	1·11	26·07	49·1	At least 100,000.
8	Halton - -	2,000	Combined	35,000	Domestic (mainly slop-water).	4·74	*0·85	11·83	17·7	At least 100,000.
9	Little Drayton -	1,550	Ditto	12,000	Strong slop water domestic.	7·57	1·41	24·44	23·9	At least 100,000.
10	Leeds - - -	450,000	Ditto	15,500,000	Trade sewage.	*1·92*	*0·68*	*11·34*	*58·1*	About 100,000.
11	Oswestry - -	9,800	Ditto	350,000	Domestic with brewery and tannery waste.	3·53	0·91	11·27	29·4	At least 100,000.
12	Sheffield - -	400,000	Ditto	14,500,000	Trade sewage.	*2·61*	*0·76*	*7·08*	*50·2*	
13	Oldham - -	—	Ditto	2,250,000	Rather weak domestic.	*3·17*	*0·77*	*5·60*	*51·2*	About 100,000.

NOTE.—The figures of analysis given in ordinary type are, as a rule, averages of three sets of twenty-four hourly a large number of chance samples drawn in all weathers. All figures for "oxygen absorbed in four hours" given with the figures for "oxygen absorbed in four hours" given in ordinary type, the latter having been obtained with

WITHOUT THE AID OF CHEMICALS.

Rate of flow through tanks (expressed in time taken to fill tank in dry weather).	Analysis of Settled Sewage. Parts per 100,000. Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.	B. Coli per c.c.	Tanks Cleaned.	Method of Disposing of Sludge.	Remarks.
5·3 hours	3·96	0·76	15·13	24·2	100 to 10,000.	Every 5 weeks	Taken by farmer.	
15·5 hours	4·72	*0·69	8·33	10·7		Every 7 weeks	Lagooned, taken by farmers when dry.	
0·93 hours	7·54	1·16	18·21	19·9		Every week	Lagooned	
4·0 hours	*1·60*	*0·37*	*5·24*	*12·8*			Lagooned	Experimental process.
average rate	*1·74*	*0·39*	*5·50*	*12·2*				
8·0 hours	*1·90*	*0·41*	*5·84*	*11·7*				
4·1 hours	3·48	0·92	10·37	22·8		Every 4 or 5 weeks.	Mixed with house ashes and taken by farmers.	
8 hours	*2·19*	*0·41*	*4·23*	*10·7*		Every week	Lagooned	Experimental process.
12 hours	*3·22*	*0·53*	*3·06*	*15·8*			Pressed and taken by farmers.	

samples drawn in dry weather, according to rate of flow. The figures of analysis given in italics are, as a rule, averages of in italics, having been obtained with "weak" permanganate, must be multiplied by 1·6 to compare approximately "strong" permanganate. * The figures are probably rather too high.

TABLE III.—TREATMENT OF

No.	Place.	Population.	System of Sewerage.	Dry weather flow of sewage (gallons).	Nature of Sewage.	Analysis of Sewage. Parts per 100,000. Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.	B. Coli per c.c.
14	Accrington -	46,300	Combined	1,180,000	Strong domestic.	5·18	0·68	9·93	43·3	At least 100,000.
15	Andover - -	5,000	Partially separate.	150,000	Domestic, with brewery waste	7·37	1·18	10·02	16·5	At least 100,000.
16	Birmingham -	865,701	Combined and partially separate.	22,000,000	Trade sewage	*3·67**	*0·98**	*20·32**	*48·4**	—
17	Burnley - -	82,000	Ditto	2,000,000	Domestic, with trades waste.	*3·32*	*0·97*	*9·98*	—	—
18	Caterham - -	1,300 (assumed.)	Separate	17,000	Very strong domestic.	13·41	1·75	17·99	42·1	At least 100,000.
19	Exeter (St. Leonards).	1,500	Partially separate.	70,000	Weak domestic.	2·86†	—	4·35	13·0	At least 100,000.
20	Exeter (Main works).	38,000	Combined	1,300,000	Domestic, with trades waste.	4·66	1·37	19·86	37·2	About 100,000.
21	Guildford - -	16,000	Partially separate.	400,000	Domestic, with brewery waste.	7·39	1·91	21·96	42·1	At least 100,000.
22	Hartley Wintney	1,600	Ditto	45,000	Ditto	A. 2·43 B. 7·47	0·68 1·79	14·61 18·64	20·1 32·7	At least 100,000.
23	Huddersfield -	100,000	Combined	7,000,000	Trade sewage	*1·00*	*0·60*	*10·40*	*40·0*‡	—
24	Knowle - -	1,600	Partially separate.	41,000	Domestic	4·02	0·71	8·07	19·4§	At least 100,000.
25	Leeds - -	450,142	Combined	16,000,000	Trade sewage	*2·57* *2·63*	*0·71* *0·90*	*11·20* *11·77*	*63·0* C. *59·8* P.	About 100,000.
26	Manchester -	575,000	Ditto	25,300,000	Ditto	*2·27*	*0·51*	*10·50*	*35·0*	10,000 to 100,000.
27	Prestolee - -	500	Separate	18,000	Very weak (slop water) domestic	0·42	0·15	3·57	5·4*	About 1,000
28	Rochdale - -	52,000	Combined	1,310,000	Domestic, with wool washings.	4·16	1·29	26·55	36·7	At least 100,000.
29	Sheffield - -	400,000	Ditto	14,500,000	Trade sewage	*2·61*	*0·76*	*7·08*	*50·2*	—
30	Slaithwiate- -	3,000	Partially separate.	140,000	Weak domestic.	1·66	0·40	4·60	10·7§	Usually 100,000.
31	York - - -	80,000	Combined and partially separate.	4,250,000	Domestic, with trades waste.	2·58	0·82	13·83	21·2	At least 100,000.

NOTE.—The figures of analysis given in ordinary type are, as a rule, averages of three sets of twenty-four hourly a large number of chance samples, drawn in all weathers. All figures for "Oxygen absorbed in four hours" given with the figures for "oxygen absorbed in four hours" given in ordinary type, the latter having been obtained with represents the average quantity of suspended matter in the Huddersfield sewage, in dry weather. § Average of

SEWAGE IN SEPTIC TANKS.

Rate of flow through tanks (expressed in time taken to fill tank in dry weather.)	Analysis of septic tank liquor. Parts per 100,000. Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.	B. Coli per c.c.	Tanks Cleaned.	Method of Disposing of Sludge.	Remarks
42 hours	0·03	0·34	8·67	19·4	At least 100,000.	Every 4 to 6 months.	Lagooned and sold when dried.	
19·3 hours	7·44	0·98	7·53	11·1	At least 100,000.	Partial removal at short intervals.	Run into trenches and covered over.	
10-12 hours	*6·12* A. *6·67* B.	*0·88* *0·54*	*15·86* *12·00*	*19·5* A. *8·10* B.	—	Roughing tanks once a week. Septic tanks periodically.	Buried in adjacent ground.	"A" represents the septic tank liquor as a whole and "B" the same liquor after it has passed through Dortmund tanks, but also after it has received 3,000,000 gallons of domestic sewage at Tyburn.
15 hours	*2·54*	*0·50*	*6·33*	*5 to 6*	—	Every six months	Sludge pressed and sold to farmers.	
—	18·48 18·09	1·06 1·38	10·15 13·89	12·6 A. 25·4 B.	About 100,000.	—	Run on to ground	Only one-third of sewage treated. The liquor represented by analysis "A" runs on to filter, while that represented by "B" runs on to land.
17·8 hours	4·12	0·65	3·64	5·7	At least 100,000.	After 2 or more years.	Lagooned	
11·5 hours	5·40	0·91	10·20	12·5	About 100,000.	Partial removal at short intervals.	Buried in fine clinker screenings.	
36·7 hours	9·11	1·00	11·42	15·9	At least 100,000.	—	Buried shallow in ground.	Experimental process. Fixed quantity treated daily.
31·7 hours	A. 3·13 B. —	0·73 —	13·16 —	15·1 —	About 100,000.	Partial removal at short intervals.	Run on to land	The samples for analysis series "A" were drawn in January and those for series "B" in August.
24 hours	*1·91*	*0·49*	*6·16*	*13·1*	1,000 to 10,000.	Every 6 months	Lagooned	Experimental process. Fixed quantity treated daily.
15·2 hours	3·46	0·52	5·62	8·4§	—	—	Spread over adjacent land.	
24 hours	*1·52* *1·95*	*0·49* *0·44*	*7·80* *6·07*	*25·7* C. *17·8* P.	10,000 to 100,000.	End of 2 years	Lagooned	Experimental process (large scale); compare series "C" with contact effluent and series "P" with percolating filter effluent.
15 hours	*2·74*	*0·37*	*8·69*	*10·8* app.	10,000 to 100,000.	—	Sent to sea	
22·0 hours	0·52	0·17	2·84	3·2*	1,000 to 10,000.	After 7½ years	Lagooned	
30·0 hours	3·74	0·67	10·92	5·3	10,000 to 100,000.	Every 6 months	Pressed and sold to farmers.	Experimental process. Fixed quantity treated daily.
24 hours	*1·96*	*0·37*	*4·19*	—	—	At long intervals	Lagooned	Experimental process.
13·6 hours	1·79	0·37	3·88	7·1§	10,000 to 100,000.	No sludge removed for over 10 years.	—	
26 hours	2·86	0·49	6·51	5·3	10,000 to 100,000.	After 21 months	Lagooned	Experimental process. Fixed quantity treated daily.

samples, drawn, in dry weather, according to rate of flow. The figures of analysis given in italics are, as a rule, averages of in italics having been obtained with "weak" permanganate must be multiplied by 1·6 to compare approximately "strong" permanganate. * Average analysis of Saltley sewage only. † Not quite dry weather samples. ‡ This figure two samples only.

TABLE IV.—CHEMICAL PRECIPITATION,

No.	Place.	System of Sewerage.	Population draining to Works.	Dry weather flow of Sewage (gallons).	Nature of Sewage.	Analysis of Sewage (Parts per 100,000).				B. Coli per c.c.
						Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.	
32	Calverley -	Combined	2,300	12,000	Strong domestic (mainly slop water).	11·82	1·80	29·55	31·90	At least 100,000
33	Chorley -	Ditto	27,000	900,000	Domestic	4·20	1·01	12·38	31·40	At least 100,000
34	Guildford -	Partially separate.	16,000	400,000	Domestic with brewery waste.	7·38	2·10	21·33	37·1	At least 100,000
6	Hendon, High Level.	Ditto	23,500	650,000	Domestic	† 3·0 app.	† 1·0 app.	11·01	*23·9	About 100,000
35	Hendon, Low Level.	Ditto	23,500	300,000	Domestic with laundry waste.	† 4·0 app.	† 1·3 app.	17·55	*33·4	About 100,000
36	Heywood -	Combined	23,500	630,000	Domestic with trade waste.	*3·37*	*0·83*	*7·89*	‡*29·0*	At least 100,000
37	Horfield -	Partially separate.	2,500	38,000	Domestic with laundry waste.	3·80	1·02	9·39	35·6	At least 100,000
38	Huddersfield	Combined	100,000	7,000,000	Trade sewage.	*1·00*	*0·60*	*10·40*	*40·0*	
39	Kingston -	—	53,454	2,750,000	Domestic with trade waste.	3·85	0·86	10·66	31·0	At least 100,000
40	Leeds -	Combined	450,000	15,500,000	Trade sewage	*1·84* *2·07*	*0·60* *0·76*	*10·8* *12·1*	*60·1* G. *62·4* P.	About 100,000
41	Maidstone -	Partially separate.	34,000	1,500,000	Domestic with brewery and tannery waste.	3·51	1·52	21·03	*34·8	At least 100,000
42	Normanton	Combined	12,600	175,000	Domestic (mainly slop water).	6·95	1·50	29·25	*55·0	At least 100,000
43	Rochdale -	Ditto	52,000	1,310,000	Domestic with wool scouring liquor.	4·16	1·29	26·55	*36·7	At least 100,000
44	Sheffield -	Ditto	400,000	14,500,000	Trade sewage.	*2·61*	*0·76*	*7·08*	*50·2*	—
45	Withnell -	Partially separate.	1,650	15,000	Strong domestic (mainly slop water).	5·35	1·23	21·19 17·22	33·9 A. 19·6 B.	At least 100,000
46	York - -	—	80,000	—	Domestic with trade waste.	2·58	0·82	13·83	21·2	At least 100,000

NOTE.—The figures of analysis given in ordinary type are, as a rule, averages of three sets of twenty-four hourly number of chance samples drawn in all weathers. All figures for "oxygen absorbed in four hours" given in italics, having been four hours" given in ordinary type, the latter having been obtained with "strong" permanganate. * These were not quite dry

FOLLOWED BY SETTLEMENT.

Precipitant used and quantity added in grains per gallon.	Rate of flow in tanks (expressed in time taken to fill tanks in dry weather).	Analysis of precipitation liquor (parts per 100,000). Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen absorbed in 4 hours.	Suspended Solids.	B. Coli. per c.c.	Tanks cleaned.	Method of Disposing of Sludge.	Remarks.
Alumino-ferric 17·5 grains based on dry weather flow.	47 hours	9·64	1·11	11·94	11·80	At least 100,000	No. 1 every month. No. 2 every two months.	Lagooned. Taken by farmer when dry.	
Alumino-ferric 9·0 grains on average flow.	Quiescent for 1–2 hours.	3·82	0·55	4·77	3·11	10,000 to 100,000	Every two fillings.	Pressed and sold to farmers.	
Alumino-ferric 8·0 grains on average flow.	10½ hours	7·34	1·33	20·04	14·6	At least 100,000	Every two days.	Pumped into trenches and covered over.	
Alumino-ferric 5 grains on average flow.	12 hours	3·62	0·42	5·50	*6·1	About 100,000	Twice a week to once a month according to position of tank in the series.	Pumped into trenches on land.	
Alumino-ferric 6·0 grains on average flow.	12 hours	4·88	0·76	7·25	*4·1	About 100,000			
Alumino-ferric 8·0 grains on average flow.	24 hours	*1·99*	*0·42*	*3·38*	*4·0*	About 100,000	—	Pressed and taken by farmers.	
Alumino-ferric 5·0 grains on average flow.	17 hours	3·31	0·32	3·12	2·5	10,000 to 100,000	Every two days.	Pressed and taken by farmers.	
Lime and copperas.	6 hours	*1·21*	*0·33*	*5·74*	*7·0*	—	—	Lagooned	
Alumino-ferric blood, charcoal, and clay, 50 grains on average flow.	6½ hours	3·64	0·44	5·17	1·5	10,000 to 100,000	First tanks every six days, second and third once a fortnight.	Pressed, dried and sold as manure.	
Lime 3 grains on average flow.	4 hours 12 hours	*1·68* *2·00*	*0·31* *0·32*	*4·61* *4·16*	*11·1* G. *6·3* P.	—	—	Lagooned	Experimental process Analysis G. refers to the general precipitation liquor and Analysis P. is for comparison with percolating filter effluent
Lime 5 grains on average flow.	1½ hours	3·53	0·99	10·71	*14·0	—	Every two weeks.	Pressed and taken by farmers.	
Alumino-ferric 6–7 grains on dry weather flow.	14½ hours	4·90	0·68	10·32	*14·0	10,000 to 100,000	Every week	Lagooned and taken by farmers when dry.	
Alumino-ferric 7·3 grains Vitriol 4·7 grains on average flow.	14½ hours	4·20	0·66	13·17	*7·8	1,000 to 10,000	Every three or four weeks.	Pressed and taken by farmers.	
Lime	Quiescent for 45 minutes.	*1·09*	*0·15*	*2·80*	*4·8*	—	—	Lagooned	
Alumino-ferric 15 grains on dry weather flow.	Quiescent for several hours.	— 4·35	— 0·47	— 7·95	— 2·0 app. B.	100 to 1,000	Every one or two fillings.	Lagooned	Analysis A. is an average analysis of Withnell sewage. Analysis B. is an average analysis made on samples of sewage drawn for comparison with the precipitation liquor.
Alumino-ferric 5·7 grains. Lime 4·3 grains on average flow.	7 hours*	2·63	0·54	7·76	8·9	About 10,000	Every four days.	Pressed and buried thick under layer of soil.	

samples drawn, in dry weather, according to rate of flow. The figures of analysis given in italics are, as a rule, averages of a large obtained with "weak" permanganate, must be multiplied by 1·6 to compare approximately with the figures for "oxygen absorbed in weather samples. † These figures are inferred. ‡ Grit is not included in this figure.

TABLE V.—CONTACT

No.	Place.	Number of contacts given.	Material.	Size of Material.	Depth of Material.	Distribution.	Average number of fillings per day. Primary beds only.	Rate of treatment per cube yard per day. Whole area included.
CRUDE SEWAGE.								Gallons.
1	Hampton -	3	Clinker	Primary—coarse Secondary—medium. Tertiary—very fine	4 ft.	None on primary beds, half pipes and grips on secondary and tertiary beds.	About 3	43 Based on dry weather flow.
2c	Leeds	2	Coke	Primary—coarse Secondary—medium.	Primary, 5ft. Secondary, 6 ft.	None	Ditto	About 32
3	Maidstone -	2	Clinker	Primary—coarse Secondary—fine	Primary, 3 ft. 4 in. Secondary, 4 ft. 4 in.	Half pipes	0·86	23·7
4	Newton -	1	Ditto	Medium to coarse	3 ft. 6 in.	Troughs	1·7	91
5	Withnell -	2	Ditto	Primary—rather coarse. Secondary—medium.	Primary, 5 ft. Secondary, 3 ft. 6 in.	Ditto	0·71	18·2
SETTLED SEWAGE.								
8	Halton -	2	Primary—coke, clinker and stone. Secondary—coke.	Primary } rather Secondary } coarse	Primary 4 ft. 3 in. Secondary, 3 ft. 3 in.	Ditto	About 4	80
13	Oldham -	1	Clinker	Medium to coarse	3 ft. to 1 ft. 6 in.	Troughs	——	About 100
11	Oswestry -	2	House cinders	Primary } medium to Secondary } coarse	All beds, 4 ft. 6 in.	Ditto	4–5	51·4
12	Sheffield -	2	Clinker	Primary } medium to Secondary } fine.	3 ft.	Grips in material.	3	60
SEPTIC TANK LIQUOR.								
15	Andover -	1	Ditto	Medium to fine	4 ft.	Half pipes	1·4	115 Based on dry weather flow.
17	Burnley -	2	Ditto	Primary—coarse Secondary—fine	- -	Troughs	2	45
19	Exeter, (St. Leonards).	1	Clinker and coke	Fine to medium	5 ft.	Half pipes	3	105
20	Exeter (Main works).	1	Clinker	Medium	4 ft. 6 in.	Ditto	2	55 Based on dry weather flow.
21	Guildford	2	Burnt ballast or clinker.	Primary—rather coarse. Secondary—rather fine.	2 ft. 6 in.	Grips in material.	2	22·7

NOTE.—(*a*) All figures for "oxygen absorbed in four hours" given in italics, having been obtained with "weak" permanganate, the latter having been obtained with strong permanganate. (*b*) The figures for albuminoid
* The figures are approximate. † These figures are averages of

BED FILTRATION.

Analysis of final effluents. Parts per 100,000.														B. Coli per c.c.	Condition of Filters.	Remarks.
Ammoniacal Nitrogen.		Albuminoid Nitrogen.		Oxidised Nitrogen.		Oxygen absorbed in 4 hours.		Incubator test. (smell.)		Suspended Solids.		Dissolved oxygen taken up in 24 hours.				
Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.			
–	0·71	–	0·11	–	2·64	–	1·31	–	12+ in 12.	–	Trace	–	0·38	About 1,000 to 100,000.	Crude sewage clogged primary beds in one year, and partially settled sewage in 4 years.	
–	*0·44*	–	*0·09*	–	*0·37*	–	*0·75*	–	–	–	*2·5*	–	–	—	Primary bed lost capacity seriously in first 4 months.	Experimental process. Large scale. Fixed quantity treated daily.
–	0·92	–	0·22	–	1·23	–	2·52	–	7+ in 8.	–	1·31	–	–	10,000 to 100,000.	Primary bed in good order after 5 years.	Experimental process. Fixed quantity treated daily
3·40	*0·59	–	*0·37	Trace	0·16	6·79	5·78	2– in 2.	6– in 6.	8·5	*6·9	–	More than 6·2	About 100,000.	Beds seriously clogged on surface after about 5 years.	
0·89	†0·63	0·41	*0·12	0·0	2·48	3·86	1·71	3– in 3.	3+ in 3.	5·5	About 1·0	–	*0·66	At least 100,000.	Primary beds becoming seriously clogged after 5 years.	Experimental process. Fixed quantity treated daily.
–	*1·54	–	*0·23	–	†0·88	–	2·52	–	2+ in 5.	–	About 3·0	–	–	About 10,000 to 100,000.	Primary beds clogged after 4 years.	
–	*1·51*	–	*0·23*	–	*0·31*	–	*0.99*	–	–	–	*5·1*	–	–	—	—	—
–	0·56	–	0·18	–	1·16	–	1·76	–	8+ in 10.	–	About 2·0	–	*0·72	About 10,000.	Primary beds clogged up after about 3 or 4 years	
–	*0·34*	–	*0·06*	–	*1·64*	–	*0·60*	–	–	–	*1·8*	–	–	—	—	Experimental process.
4·82	4·10	*0·60	*0·52	0·0	*0·43	4·26	4·02	3– in 3.	1+ in 11.	9·8	9·6	–	*2·77	About 10,000 to 100,000.	Material had to be washed after about 4 years.	
–	–	–	*0·06*	–	*1·06*	–	*0·78*	–	–	–	–	–	–	—	Material in No. 5 primary bed had to be washed after 3½ years.	
1·00	0·55	–	0·11	1·49	*1·69	0·85	1·08	3+ in 3.	6+ in 6.	0·9	About 0·6	–	*0·62 ‡‡	About 100,000.	Material showing signs of clogging after 9 years' work.	
3·12	1·61	†0·47	0·31	*0·28	*1·63	3·67	4·42	3– in 3.	7+ in 14.	4·6	5·5	–	*1·69	About 100,000.	Beds had lost nearly half their water capacity after about 3 years.	
–	‡‡1·08	–	†0·32	–	1·22	–	2·77	–	4+ in 7.	–	About 1·0	–	–	About 100,000.	Primary beds had lost nearly ⅕ of their capacity after about 4 years' work	Practically fixed quantity treated daily.

must be multiplied by 1·6 to compare approximately with the figures for "oxygen absorbed in four hours" given in ordinary type, nitrogen in ordinary type may probably be rather too high in the case of some of the effluents.
two samples only. ‡ These are averages of three samples only.

TABLE V.—CONTACT

No.	Place.	Number of contacts given.	Material.	Size of material.	Depth of Material.	Distribution	Average number of fillings per day. Primary beds only.	Rate of treatment per cube yard per day. Whole area included.
SEPTIC TANK LIQUOR (*continued*).								
22	Hartley Wintney.	1	Clinker	Fine	4 ft.	Half pipes	2·0	Gallons. 73 Based on dry weather flow.
23	Huddersfield	2	Ditto	Primary—coarse Secondary—medium	Primary, 3 ft. 9 in. Secondary, 2 ft. 11 in.	Grits in material.	2·5	71
25c	Leeds -	2	Primary—clinker Secondary—coke.	Primary—medium Secondary—medium.	Primary 5 ft. Secondary, 6 ft.	Ditto	1·5	45
26	Manchester	1	Clinker	Medium	3 ft. 4 in.	Ditto	2 to 3	77
29	Sheffield -	2	Ditto	Primary—rather coarse. Secondary—rather fine.	3 ft.	Ditto	3	About 60
30	Slaithwaite-	1	Ditto	Medium	5 ft.	Troughs	1·5	62
PRECIPITATION LIQUOR.								
32	Calverley -	1	Ditto	Fine to coarse	3 ft.	Ditto	About 0·7	30 Based on dry weather flow.
6 & 35	Hendon -	1	Pan breeze, burnt ballast and broken brick.	Fine to medium	5 ft.	Half pipe	2·5	—
36	Heywood -	1	Sand Ashes Coke	Very fine Medium Coarse.	4 ft. 3 in.	Troughs	3	174
39	Kingston -	1	Clinker or coke	Medium	3 ft.	Ditto	4	250
40	Leeds -	1	Clinker	Medium	3 ft. 6 in.	None	3	—
38	Huddersfield	2	Ditto	Primary—medium Secondary—fine medium.	3 ft. 3 in.	—	2·5	100

NOTE.—(*a*) All figures for "oxygen absorbed in four hours" given in italics, having been obtained with "weak" permanganate, the latter having been obtained with strong permanganate. (*b*) The figures for albuminoid
* These figures are approximate. † These figures are averages of two samples only. ‡ These are averages

BED FILTRATION—*continued.*

Analysis of final effluents. Parts per 100,000.														B. Coli. per c.c.	Condition of Filters.	Remarks.
Ammoniacal Nitrogen.		Albuminoid Nitrogen.		Oxidised Nitrogen.		Oxygen absorbed in 4 hours.		Incubator test. (smell.)		Suspended Solids.		Dissolved oxygen taken up in 24 hours.				
Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.			
1·16	3·20	0·27	0·38	1·22	1·02	3·14	3·26	3+ in 3.	2+ in 7.	3·3	7·2	–	*2·36	About 1,000 to 10,000.	Beds seriously clogged after about 5 years.	
–	*0·18*	–	*0·15*	–	*0·49*	–	*1·53*	–	–	–	*1·8*	–	–	—	Primary bed lost 74 per cent. of its capacity after 4½ years.	Experimental process.
–	*0·28*	–	*0·05*	–	*1·75*	–	*0·51*	–	–	–	*0·3*	–	–	About 1,000 to 10,000.	Primary bed lost 80 per cent. of its capacity after 4 years.	Experimental process.
–	*1·62*	–	*0·15*	–	*0·30*	–	*2·73*	–	–	–	*5·4*	–	§41 %	About 1,000 to 10,000.	—	
–	*0·48*	–	*0·07*	–	*1·21*	–	*0·72*	–	–	–	–	–	‖0·43	—	—	Experimental process.
–	‡0·84	–	‡0·17	–	0·57	–	2·15	–	2+ in 7.	–	About 2·0	–	1·52	About 10,000.	Surface material badly clogged after 4 years.	Practically fixed quantity treated daily.
–	2·67	–	*0·30	–	0·33	–	3·57	–	4+ in 13.	–	8·8	–	*1·14	About 1,000 to 10,000,	Beds still in good order after 10 years' work.	
1·72	–	†0·16	–	1·22	–	2·07	–	3+ in 3.	–	Trace	–	–	–	About 1,000 to 10,000,	Beds still in good order after 6 years.	
–	*1·87*	–	*0·18*	–	*0·46*	–	*0·96*	–	–	–	–	–	–	—	Bed still good after 10 years. Top ½ inch of sand is taken off once a month and allowed to weather.	
1·96	1·45	†0·19	0·12	1·22	1·53	0·84	0·96	3+ in 3.	7+ in 7.	About 1·0	About 1·0	–	0·18	About 1,000 to 10,000.	Coke bed retains 20 per cent. of its empty tank capacity after nearly 8 years. Clinker bed retains 32 per cent. after nearly 4 years.	
–	*1·47*	–	*0·19*	–	*0·07*	–	*1·45*	–	–	–	*6·4*	–	–	—	Bed lost capacity rapidly owing to consolidation of material.	
–	*0·09*	–	*0·08*	–	*0·86*	–	*1·10*	–	–	–	*2·1*	–	–	—	No. 10 bed lost 68 per cent. of its capacity in 6 years.	

must be multiplied by 1·6 to compare approximately with the figures for "oxygen absorbed in four hours" given in ordinary type, nitrogen in ordinary type may probably be rather too high in the case of some of the effluents.
of three samples only. § Percentage of dissolved oxygen taken up in forty-eight hours at 80°F. ‖ At 60°F.

TABLE VI.—PERCOLATING

No.	Place.	Material used in Filters.	Size of Material.	Depth of Material.	Distribution.	How Liquid is delivered to Filter.	Rate of filtration per square yard per day.	Rate of filtration per cube yard per day.
							Gallons.	Gallons.
CRUDE SEWAGE.								
6	Hendon -	Clinker	Medium	8 or 10 feet	Tipping troughs	Continuously	125	About 40
2D	Leeds -	Ditto	Ditto	10 feet	Ditto	Ditto	83	25
2L	Leeds -	Ditto	Very coarse	11½ feet	Sprinkler	Intermittently	200	52
SETTLED SEWAGE.								
7	Clifton -	Cinders or sand and cinders	Fine to coarse Very fine to coarse	4 feet	By fine material	Ditto	20·8	15·6
							Based on dry weather flow.	
10	Leeds -	Coke	Coarse	9 ft. 6 ins.	Sprinkler	Continuously	200	63
9	Little Drayton.	Granite	Medium	7 ft. 6 ins.	Tipping troughs	Ditto	48·5	19·5
SEPTIC TANK LIQUOR.								
14	Accrington	Coke or clinker	Coarse	9 ft. 3 ins. to 7 feet.	Sprinklers	Ditto	425	140
16	Birmingham	Granite, quartzite, slag, etc.	Coarse	6 feet	Nozzles, etc.	Ditto	165	82·5
18	Caterham -	Coke	Medium to coarse	5 feet	Perforated pipes	Intermittently	51	30·7
23	Huddersfield	Clinker	Coarse	7 feet	Sprinkler	Continuously	258	110
24	Knowle -	Ditto	Ditto	6 feet	Stoddart trays	Ditto	1,000	2,000
25D	Leeds	Coke	Ditto	9 ft. 6 ins.	Sprinkler	Ditto	200	63

NOTE.—(*a*) All figures for "oxygen absorbed in four hours" given in italics, having been obtained with "weak" permanganate, the latter having been obtained with "strong" permanganate. (*b*) The figures for albuminoid

* These figures are approximate. † This analysis

FILTERS

Analysis of Final Effluent (Unsettled).																
Ammoniacal Nitrogen.		Albuminoid Nitrogen.		Oxidised Nitrogen.		Oxygen absorbed in 4 hours.		Incubator test (by smell).		Dissolved Oxygen taken up in 24 hours.		Suspended Solids.		B. Coli. per c.c.	Condition of Filters.	Remarks.
Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.			
1·06	0·57	0·28	0·13	2·37	3·51	2·65	1·87	3 + in 3.	9 + in 9.	–	*0·62	6·3	5·2	—	No. 2 Filter (8 feet) good after 8 years.	Experimental Duca Filters. Fixe quantity treated daily.
–	*0·19*	–	*0·05*	–	*1·21*	–	*0·34*	–	–	–	–	–	–	About 1,000.	Clogged after 1 month's work.	Ducat Experimental Filter. Fixed quantity treated daily.
–	*0·72*	–	*0·27*	–	*0·35*	–	*3·09*	–	–	–	–	–	*21·0*	About 10,000.	Choked with growth after 21 months.	Experimental "Leeds" Filter. Fixed quantity treated daily.
0·80	0·95	0·10	0·20	0·82	1·16	1·10	2·06	3 + in 3.	5 + in 7.	–	0·93	3·3	5·6	100 to 10,000.	Sand filter good after 14 years.	
–	*0·31*	–	*0·13*	–	*1·27*	–	*1·71*	–	–	–	–	–	*12·0*	—	Unchanged after 1 year.	Experimental process. Fixed quantity treated daily.
0·78	0·57	0·22	0·18	3·60	4·51	2·92	2·45	3 + in 3.	4 + in 4.	0·74	0·92	10·1	8·0	1,000 to 10,000.	Necessary to wash upper part of material after 3 or 4 years.	
1·07	1·33	0·27	0·25	2·24	1·60	5·08	3·02	4 + in 4.	11 + in 11.	–	*0·96	20·0	8·9	Ditto	Good after 4 to 8 years.	
2·86	–	*0·29*	–	*2·11*	–	*2·58*	–	*all* +	–	–	–	*7·3*	–	—	—	
6·77	8·88	0·42	0·41	8·90	7·95	5·22	5·11	4 + in 4.	7 + in 7.	–	0·80	*3·7	3·8	About 1,000.	Good after 10 years.	Fixed quantity treated daily.
–	†*0·23*	–	†*0·09*	–	†*1·03*	–	†*1·29*	–	–	–	–	–	–	Ditto	Good after 1 year	Experimental process. Fixed quantity treated daily.
3·19	4·07	0·34	0·48	*0·90	0·60	2·70	4·11	3 – in 3.	5 + in 12.	–	*2·28	3·77	3·9	About 100,000.	Good after about 4 years.	
–	*0·51*	–	*0·14*	–	*1·08*	–	*1·60*	–	–	–	–	–	*11·4*	About 1,000.	Good after 4 years' work. Bed twice flushed out with town's water.	Experimental process, Fixed quantity treated daily.

must be multiplied by 1·6 to compare approximately with the figures for "oxygen absorbed in four hours," given in ordinary type, nitrogen, in ordinary type, may probably be rather too high in the case of some of the effluents.
was made after suspended solids had been settled out.

TABLE VI.—PERCOLATING

No.	Place.	Material used in Filters.	Size of Material.	Depth of Material.	Distribution.	How Liquid is delivered to Filter.	Rate of filtration per square yard per day.	Rate of filtration per cube yard per day.
SEPTIC TANK LIQUOR (*continued*).							Gallons.	Gallons.
27	Prestolee -	Cinders and gravel	Fine to coarse	5 feet	By fine material	Inter-mittently	92·7	55·6
28	Rochdale -	Coke	Coarse	9 feet	Sprinkler	Continuously	424	141
31	York - -	Clinker, coke, slag or broken brick.	Ditto.	6 ft. 6 ins. by 7 ft. 8 ins.	Ditto.	Ditto.	360	About 150
PRECIPITATION LIQUOR.								
33	Chorley -	Sand, polarite, and gravel.	Very fine to coarse	3 feet	By fine material	Inter-mittently	525	525
37	Horfield -	Clinker	Coarse	7 ft. 5 ins.	Stoddart trays	Continuously	478	190
40P	Leeds -	Coke	Ditto.	6 feet	Sprinkler	Inter-mittently	100	50
42	Normanton-	Sand, polarite, and gravel.	Very fine to coarse	3 ft. 3 ins.	By fine material	Ditto.	—	—
45	Withnell -	Ditto.	Ditto.	3 feet	Ditto.	Ditto.	68·6 Based on dry weather flow.	63·5
6 and 35	Hendon -	Coke breeze, burnt ballast, and broken brick.	Fine to coarse	5 feet	Ditto.	Ditto.	—	—

NOTE.—All figures for "oxygen absorbed in four hours" given in italics, having been obtained with "weak" permanganate the latter having been obtained with "strong" permanganate. (*b*) The figures for albuminoid nitrogen in

FILTERS—*continued.*

Analysis of Final Effluent (Unsettled).																
Ammoniacal Nitrogen.		Albuminoid Nitrogen.		Oxidised Nitrogen.		Oxygen absorbed in 4 hours.		Incubator test (by smell).		Dissolved Oxygen taken up in 24 hours.		Suspended Solids.		B. Coli. per c.c.	Condition of Filters.	Remarks.
Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.			
0·13	0·05	0·03	0·02	0·33	0·90	0·31	0·41	3 + in 3.	6 + in 6.	–	*0·04	None	None	100 to 1,000.	Good after 8 years.	
–	0·08	–	0·10	–	*2·76	–	2·56	–	5 + in .	–	*0·32	–	7·4	About 100 to 1,000.	Good after 7 years.	Fixed quantity treated daily
0·10	0·25	0·07	0·15	2·25	2·11	1·17	1·82	3 + in 3.	7 + in 7.		0·32	1·80	5·0	Ditto.	Good after 4 and 6 years.	Ditto.
1·07	0·56	0·09	0·11	2·35	3·00	1·03	0·98	3 + in 3.	12 + in 12.	–	0·18	Trace	Trace	About 1,000 to 10,000.	Good after 12 years.	
1·69	2·26	0·15	0·23	2·19	*1·19	1·60	2·47	3 + in 3.	12 + in 12.	–	*0·54	3·65	7·0	About 10,000.	Good after 5 years.	
–	*0.34*	–	*0·07*	–	*1·66*	–	*0·67*	–	–	–	–	–	*2·0*	—	Good after 1 year.	Experimental process. Fixed quantity treated daily. Filter worked subsequently at double this rate with good results.
2·58	1·42	0·16	0·10	1·33	3·00	1·86	1·27	3 + in 3.	10 + in 11.	–	*0·69	Trace	Trace	About 1,000 to 10,000.	Good after 10 years.	Fixed quantity treated daily.
2·71	1·68	0·16	0·08	1·62	0·84	1·65	1·29	3 + in 3.	3 + in 4.	0·49	0·28	Trace	Trace	About 100 to 1,000.	Good after 6 and 12 years.	
1·28	–	0·09	–	1·56	–	1·48	–	3 + in 3.	–	–	–	Trace	–	About 1,000.	Good after 7 years.	

must be multiplied by 1·6 to compare approximately with the figures for "oxygen absorbed in four hours," given in ordinary type ordinary type, may probably be rather too high in the case of some of the effluents. * These figures are approximate.

TABLE VII.—PERCOLATING FILTERS.

Supplementary Table showing analysis of *Settled* Effluents.

No.	Place.	How Effluent from Continuous Filter is settled.	Analysis of Settled Effluent. Parts per 100,000.														Remarks.
			Ammoniacal Nitrogen.		Albuminoid Nitrogen.		Oxidized Nitrogen.		Oxygen absorbed in 4 hours.		Incubator Test (by smell).		Suspended Solids.		Dissolved Oxygen taken up in 24 hours.		
			Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	Hourly.	Chance.	
Crude Sewage.																	
2	Leeds - -	Tank.	–	*0·61*	–	*0·16*	–	*0·44*	–	*1·47*	–	–	–	*6·1*	–	–	Experimental "Leeds" Filter. Fixed quantity treated daily.
		Fine filtered.	–	*0·52*	–	*0·10*	–	*0·59*	–	*0·93*	–	–	–	*3·5*	–	–	
Settled Sewage.																	
10	Leeds - -	Filtered through fine material.	–	*0·27*	–	*0·07*	–	*1·40*	–	*0·90*	–	–	–	*6·0*	–	–	Experimental process. Fixed quantity treated daily.
Septic Tank Liquor.																	
14	Accrington -	Tanks. One hour continuous flow settlement.	0·58	0·91	0·06	0·16	2·20	1·69	2·69	2·36	3 + in 3	13 + in 13	3·60	5·49	–	0·48*	
16	Birmingham -	Dortmund Tanks.	*3·12*	–	*0·17*	–	*1·70*	–	*2·01*	–	*all* +	–	*1·8*	–	–	–	Large scale.
18	Caterham -	Passed through tank filled with coarse flints.	6·84	9·21	0·33	0·37	8·52	6·67	3·77	4·03	4 + in 4	11 + in 11	0·8	1 to 2	–	0·60	Only one-third of sewage filtered. Fixed quantity treated daily
25p	Leeds - -	Settled, or filtered through fine material.	–	*0·51*	–	*0·08*	–	*1·06*	–	*0·70*	–	–	–	*3·0*	–	–	Experimental process. Fixed quantity treated daily.
28	Rochdale -	Tanks. Two hours continuous flow settlement.	6·47	0·08*	0·13	0·08†	2·18	2·46*	1·68	1·46	3 + in 3	8 + in 8	2·2	4·50	–	0·29*	Experimental process. Fixed quantity treated daily.

Note. (*a*) The figures for oxygen absorbed in four hours given in italics, having been obtained with "weak permanganate," must be multiplied by 1·6 to compare approximately with the figures for "oxygen absorbed in four hours," given in ordinary type, the latter having been obtained with "strong" permanganate.

(*b*) The figures for albuminoid nitrogen in ordinary type may probably be rather too high in some of the above effluents.

* These figures are approximate. † This is an average of only two samples.

PART III.—PURIFICATION OF SEWAGE BY TREATMENT ON LAND.

Introductory Remarks.

192. There can be no doubt that, where the soil is suitable and the area of land sufficient, the organic matters in sewage can be thoroughly oxidised by land treatment.

This fact is well established, not only by investigations made by earlier Commissions, but also by wide general experience.

The investigations of earlier Commissions did not, however, extend to the bacteriological side of the question, and for this reason, and in order to compare the treatment of sewage on land with its treatment by other methods, we considered it necessary to examine the working of some sewage farms.

Prior to commencing our investigations, a large number of sewage farms were visited, and we ultimately selected, for systematic observation, the following farms :—

Aldershot Camp	Sand.
Croydon (Beddington)	Gravelly loam.
Nottingham	Light loam.
Cambridge	„ „
South Norwood	Heavy loam and clay.
Leicester	„ „ „ „
Altrincham	Peaty soil and sand.
Rugby (high level farm)	Heavy loam.

Some few samples of effluent were also taken from, and some observations made at, Luton (chalk), Worsley (peat and gravel), Hemsworth (clayey soil), Derby County Asylum (stiff soil overlying red clay), Lindfield (clayey soil), Sandhurst (sandy soil), and Woking (Bagshot sand).

Our investigations extended over a period of more than two years, and detailed particulars in regard to them are contained in the Reports made to us by our officers, which were published as supplementary volumes to our Fourth Report.

Comparison of Effluents from Land and from Artificial Filters.

193. Judged by chemical analysis, both classes of effluent possess similar qualities.

As regards the eight farms which we have had under observation, the average purification, calculated on the atmospheric oxygen used up, and giving credit for the oxygen contained in the effluent in the form of nitrate, was about 98 per cent. It would have been rather higher than this if the suspended solids had been eliminated from those effluents which contained them.

As regards seven contact bed plants, which we have examined, the average purification on the same basis, but eliminating the suspended solids, was 93·4 per cent.

As regards six installations of percolating filters, our analyses show that the average purification, after eliminating the suspended solids, was 99·4 per cent.

The following tables, A and B, give the average figures of the chemical analyses of the sewage and effluents at the eight farms; Table C gives certain percentages for each farm.

Table A—Table of Average Figures showing the Chemical

Name of Farm.	Altrincham.	Aldershot Camp.	Croydon (Beddington).
Number of Samples of Sewage Examined.	4 Chance samples of sewage and 5 of lagoon liquor.	9 Chance samples and 3 sets of hourly samples.	* 5 to 7 Chance samples and 7 sets of hourly samples.
Parts per 100,000 *by weight.*	Average.	Average.	Average.
Total Nitrogen :—Chance samples.	2·06 to 5·01 = **3·56**	12·45 to 24·89 = **17·6**	6·82 to 13·42 = **9·50**
Hourly samples.	—	12·31 to 14·24 = **13·3**	6·42 to 7·59 = **7·18**
Ammoniacal nitrogen : — Chance samples.	0·69 to 3·69 = **2·29**	8·26 to 16·94 = **12·30**	4·15 to 9·71 = **7·34**
Hourly samples.	—	7·60 to 8·21 = **7·87**	4·18 to 5·11 = **4·50**
Total organic nitrogen :—Chance samples.	0·69 to 3·69 = **2·29**	3·39 to 9·10 = **5·35**	2·03 to 4·06 = **3·37**
Hourly samples.	—	4·25 to 6·18 = **5·06**	1·31 to 2·88 = **2·07**
Albuminoid nitrogen : — Chance samples.	0·20 to 1·14 = **0·62**	2·05 to 3·63 = **2·77**	0·99 to 2·36 = **1·72**
Hourly samples.	—	1·54 to 1·69 = **1·62**	0·59 to 1·12 = **0·91**
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in four hours* :—Chance samples.	2·29 to 6·98 = **5·22**	20·68 to 38·47 = **25·94**	7·91 to 18·73 = **13·70**
Hourly samples.	—	19·54 to 22·40 = **20·79**	7·85 to 17·45 = **12·48**
Chlorine :—Chance samples.	7·22 to 12·88 = **9·43**	8·90 (?) to 13·98 = **11·38**	5·70 to 10·50 = **8·15**
Hourly samples.	—	11·36 to 19·78 = **14·98**	7·86 to 9·22 = **8·34**
Solids in Suspension (gravimetrically) :—Hourly samples.	—	32·0 to 39·8 = **36·6**	21·2 to 53·0 = **34·5**
"Cellulose" in Solids in Suspension :—Hourly samples.	—	9·0 to 12·68 = **10·79**	—
Parts per 100,000 *by Volume.*			
Solids in Suspension, as determined by Centrifuge :—Chance samples.†	27 to 99 = **72** 2 sewages and 3 lagoon liqours.	—	—
Hourly samples.†	—	148 to 216 = **173**	173 to 356 = **218**
*Ratio of Solids in Suspension to Centrifuge solids : — Hourly samples.	—	1 : 3·9 to 1 : 5·4 } = **1 : 4·7**	1 : 4·8 to 1 : 8·2 } = **1 : 6·6**
Ratio of "Celluloses" to Suspended Solids (grav.) :—Hourly samples.	—	1 : 8·1 to 1 : 11.2 } = **1 : 9·7**	1 : 3·6 to 1 : 6·2 } = **1 : 4·8**

*Note.—This is a comparison of a figure expressing weight with one expressing volume.

†These figures express the *volumes* of the muds.

Composition of the Sewages at the selected Sewage Farms.

Cambridge.	Leicester.	Nottingham.	Rugby.	South Norwood.
5 Chance samples and 3 sets of hourly samples.	5 Chance samples and 3 sets of hourly samples.	4 Chance samples and 3 sets of hourly samples.	8 Chance samples and 3 sets of hourly samples.	4 to 7 Chance samples and 7 sets of hourly samples.
Average.	Average.	Average.	Average.	Average.
1·50 to 11·52 = **3·94**	2·90 to 8·61 = **5·57**	4·68 to 7·86 = **6·39**	2·80 to 14·94 = **9·95**	3·52 to 10·84 = **7·07**
5·60 to 5·80 = **5·71**	7·32 to 9·16 = **8·12**	7·53 to 7·82 = **7·69**	9·39 to 9·99 = **9·65**	4·46 to 5·63 = **5·20**
0·89 to 7·31 = **2·41**	2·90 to 8·61 = **5·57**	3·21 to 5·32 = **3·92**	1·95 to 11·21 = **7·37**	5·35 to 7·60 = **6·50**
3·77 to 3·85 = **3·82**	7·32 to 9·16 = **8·12**	3·08 to 4·53 = **3·98**	5·74 to 6·46 = **6·11**	3·15 to 4·05 = **3·54**
0·39 to 4·09 = **1·29***	1·18 to 2·41 = **1·68***	1·47 to 4·24 = **2·42***	1·61 to 5·57 = **2·54**	2·04 to 3·24 = **2·55**
1·73 to 1·95 = **1·88**	2·10 to 2·53 = **2·34**	2·56 to 4·21 = **3·15**	2·87 to 3·55 = **3·29**	1·02 to 1·90 = **1·49**
0·28 to 1·52 = **0·62**	0·66 to 1·70 = **1·11**	1·18 to 2·63 = **1·77**	0·40 to 2·84 = **1·49**	0·98 to 1·23 = **1·07**
0·89 to 0·96 = **0·91**	0·97 to 1·44 = **1·19**	1·17 to 1·99 = **1·45**	1·56 to 1·80 = **1·73**	0·55 to 1·04 = **0·67**
2·07 to 17·81 = **6·99**	7·77 to 16·41 = **12·45**	10·97 to 25·06 = **17·64**	3·55 to 33·31 = **15·0**	6·74 to 20·08 = **11·40**
9·49 to 10·68 = **10·08**	20·28 to 24·83 = **22·35**	21·03 to 26·29 = **23·12**	17·55 to 19·18 = **18·44**	5·43 to 9·77 = **7·71**
4·95 to 10·30 = **6·37**	3·51 to 11·94 = **8·10**	9·66 to 23·42 = **16·35**	4·86 to 18·30 = **11·68**	7·28 to 8·88 = **7·87**
7·90 to 8·74 = **8·45**	12·50 to 13·84 = **13·38**	11·25 to 15·36 = **13·68**	9·36 to 10·46 = **9·99**	7·08 to 8·00 = **7·45**
23·8 to 28·6 = **26·5**	33·6 to 34·8 = **34·1**	34·4 to 79·2 = **51·9†**	43·0 to 50·6 = **47·3**	9·6 to 38·2 = **21·9**
3·84 to 5·08 = **4·48**	6·56 and 5·80 = **6·18**	5·32 to 15·08 = **8·88†**	5·88 to 7·92 = **7·22**	—
—	—	—	—	—
146 to 176 = **160**	160 to 261 = **196**	—	258 to 345 = **304**	80 to 245 = **139**
1 : 5·5 to 1 : 6·5 = **1 : 6·0**	1 : 4·8 to 1 : 7·5 = **1 : 5·8**	—	1 : 6·0 to 1 : 7·1 = **1 : 6·4**	1 : 4·7 to 1 : 9·1 = **1 : ·6**
1 : 5·6 to 1 : 6·2 = **1 : 5·9**	1 : 5·3 to 1 : 5·8 = **1 : 5·6**	1 : 5·3 to 1 : 6·7 = **1 : 6·2**	1 : 6·1 to 1 : 7·3 = **1 : 6·6**	—
* This figure is possibly too low.	* This figure is possibly too low.	*This figure is probably too low. †These figures are probably higher than the normal.		

TABLE B.—TABLE WITH SOME OF THE AVERAGE FIGURES SHOWING THE CHEMICAL

NAME OF FARM.	ALTRINCHAM.	ALDERSHOT CAMP.	CROYDON (BEDDINGTON.)
Number of samples of effluents examined.*	14 to 16	16 to 18	15 to 16 (Of the final effluents two were over 2 fields only).
Parts per 100,000 *by weight.*	Average.	Average.	Average.
Total nitrogen	1·36 to 4·99=**2·22**	3·69 to 8·99=**6·0**	1·02 to 3·49=**2·20**
Ammoniacal nitrogen	0·65 to 1·87=**1·23**	0·91 to 4·98=**1·85**	0·23 to 3·10=**1·48**
Albuminoid nitrogen	0·07 to 0·25=**0·13**	0·12 to 0·47=**0·26**	0·06 to 0·23=**0·14**
Total organic nitrogen	0·10 (?) to 0·45=**0·26**	—	0·09 to 0·55=**0·26**
Nitric + nitrous nitrogen	0·0 to 3·64=**0·76**	0·0 (?) to 5·97=**3·21**	0·03 to 1·43=**0·37**
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in four hours.*	0·92 to 2·65=**1·75**	1·02 to 5·68=**2·72**	0·90 to 2·09=**1·41**
Incubator test (as judged by smell).	**81**% passed (16 samples tested.)	**89**% passed (18 samples tested.)	**73**% passed (15 samples tested.)
* Some of the effluents were subjected to more tests than others.			

TABLE C.—TABLE SHOWING APPROXIMATELY THE PERCENTAGE CHEMICAL PURIFICATION (a) ALBUMINOID NITROGEN AND (b)

NAME OF FARM.	ALTRINCHAM.	ALDERSHOT CAMP.	CROYDON (BEDDINGTON).
(a) Calculated on Albuminoid nitrogen.	**79**%* On Chance samples of sewages and lagoon liquors together.	**94**% on Chance samples.	**92**% on Chance samples.
		84% on Hourly samples.	**89**% on Hourly samples.
(b) Calculated on "Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in four hours.*	**67**%*	**90**% on Chance samples.	**90**% on Chance samples.
		87% on Hourly samples.	**89**% on Hourly samples.
	*This calculation is very approximate and of doubtful value.		

Composition of the Final and General Effluents at the selected Sewage Farms.

Cambridge.	Leicester.	Nottingham.	Rugby.	South Norwood.
17 to 18	8 to 13	13	16 to 19	11 effluents (total nitrogen and "oxygen absorbed"); 6 effluents (ammoniacal and albuminoid nitrogen). These include three 2-field effluents.
Average.	Average.	Average.	Average.	Average.
1·48 to 3·19=**2·09**	1·84 to 3·64=**2·53**	1·41 to 3·45=**2·27**	1·39 to 2·96=**2·31**	0·55 to 2·83=**2·30**
0·22 to 1·31=**0·65**	0·59 to 2·81=**1·65**	0·01 to 0·29=**0·13**	0·97 to 2·81=**1·62**	0·02 to 1·55=**0·87**
0·04 to 0·18=**0·09**	0·07 to 0·35=**0·20**	0·01 to 0·10=**0·03**	0·08 to 0·39=**0·18**	0·07 to 0·14=**0·10**
0·04 (?) to 0·42=**0·21**	0·18 to 0·63=**0·45**		—	—
0·69 to 2·25=**1·26**	0·0 to 1·73=**0·51**	1·25 to 3·29=**2·06** and 1·24 to 1·71 in four later samples.	0·0 to 1·59=**0·52**	0·14 to 0·74 (?)=**0·39**
0·16 to 1·31=**0·81**	1·70 to 4·47=**2·50**	0·05 to 0·37=**0·19**	0·72 to 2·16=**1·41**	0·97 to 1·73=**1·44**
94% passed (18 samples tested.)	**92**% passed (13 samples tested.)	**100**% passed (17 samples tested.)	**75**% passed (20 samples tested.)	**75**% passed (12 samples tested.)

tion on the various Sewages effected at the selected Farms, as calculated "Oxygen Absorbed" from Permanganate.

Cambridge.	Leicester.	Nottingham.	Rugby.	South Norwood.
85% on Chance samples.	**82**% on Chance samples.	**99**% on Chance samples.	**88**% on Chance samples.	**91**% on Chance samples.
90% on Hourly samples.	**85**% on Hourly samples.	**98**% on Hourly samples.	**89**% on Hourly samples.	**85**% on Hourly samples.
88% on Chance samples.	**80**% on Chance samples.	**99**% on Chance samples.	**91**% on Chance samples.	**87**% on Chance samples.
92% on Hourly samples.	**88**% on Hourly samples.	**99**% on Hourly samples.	**92**% on Hourly samples.	**81**% on Hourly samples.

These Tables show that the strength of the several sewages varied somewhat widely, that the average quality of the effluents from the several farms also varied, and further, that the effluents from the same farm were by no means of uniform quality.

Nottingham was the only farm from which none of the effluents which were examined putrefied upon incubation, and in this case the amount of sewage treated was only 10,750 gallons per acre per day, and very little storm water was treated.

Speaking generally, the effluents which we have examined from artificial filters, as at present constructed and used, are not equal in purity to effluents from the best land, when treating a comparatively small quantity per acre, as at Nottingham ; but effluents from heavy land are often of very inferior quality. Moreover, in the case of some kinds of land, we think that the danger of some of the sewage escaping in an unpurified condition is greater than it is in the case of artificial filters, assuming equally careful management in the two cases.

Bacteriological Character of Effluents.

194. Our investigations have not shown that there is any essential bacteriological distinction between effluents from land and effluents from artificial filters, though effluents from land usually contain fewer micro-organisms than effluents from the artificial filters which are at present in use. The bacteria in the filter effluents can, however, be largely reduced, if this is necessary, by some additional process, such as sand filtration or sterilization,* but for the reasons which are given under the section of this Report dealing with standards, we do not consider that the further process would usually be required.

There is, no doubt, a greater retardation in the passage of an excremental organism through soil than through artificial filters, at the rates of working generally followed in the two cases : this is probably a factor of importance in relation to the life and virulence of certain pathogenic microbes.

The following table gives the average figures for the bacteriological analysis of the final effluents from the eight sewage farms, the figures in brackets shewing the percentage reduction in each case upon the original sewage treated.

	Altrincham.	Aldershot Camp.	Croydon (Beddington).	Cambridge.	Leicester.	Nottingham ‡.	Rugby.	South Norwood.
Total number of bacteria (Gelatine at 20°C.)	263,400 (99%)	183,266 (99%)	1,413,200 (95%)	711,476 (94%)	532,777 (95%)	Frequently less than 1,000.	637,133 (97%)	778,322 (98%)
Total number of bacteria (Agar at 37° C.)	7,275 (99%)	37,308 (99%)	112,000 (97%)	78,327 (94%)	70,500 (95%)	ditto	81,526 (97%)	35,157 (99%)
B. Coli. (†)	At least 100, but less than 1,000 per c.c.	At least 1,000, but less than 10,000 per c.c.	At least 1,000, but less than 10,000 per c.c.	At least 1,000, but less than 10,000 per c.c.	At least 1,000, but less than 10,000 per c.c.	Results variable : but usually very satisfactory in a relative sense.	At least 1,000, but less than 10,000 per c.c.	At least 100, but less than 1,000 per c.c.
B. Enteritidis Sporogenes test.	At least 1, but less than 10 per c.c.	At least 10, but less than 100 per c.c.	At least 10, but less than 100 per c.c.	At least 10, but less than 100 per c.c.	At least 10, but less than 100 per c.c.		At least 10, but less than 100 per c.c.	At least 10, but less than 100 per c.c.
Neutral red broth test (†).	+ ·01. c.c. − ·001 c.c.	+ ·01 c.c. − ·001 c.c.	+ ·001 c.c. − ·0001 c.c.		+ ·001 c.c. − ·001 c.c.		+ ·01 c.c. − ·0001 c.c.	

* *See* Dr. Houston's Report on Sterilization, Appendix IV.

(†) These averages are only approximate.

(‡) The effluents from the Nottingham farm stand in a class by themselves. Some of them were so pure bacteriologically as to resemble drinking water, but still the figures were variable. (For details, cf. Bacteriological Report to the Commission by Dr. A. C. Houston, Fourth Report, Vol. IV., Part III.)

From a bacteriological point of view, the treatment of sewage on land, may, under favourable conditions, reduce the bacteria to quite a remarkable extent. This is shown in the foregoing Table, the reduction both in the total number of bacteria and in the bacteria growing at 37° C. (blood heat) varying from 94 per cent. to 99 per cent. But, notwithstanding this large percentage reduction, it will be seen from Dr. Houston's detailed Report* that the number of microbes of undesirable sort remaining in the effluent may often be very great.

Volume of Sewage which can be Treated on Land.

195. The witnesses whom we examined on the question of the land treatment of sewage were not unanimous as to the basis on which the extent of land required should be calculated. Mr. F. Scudder and Mr. Santo Crimp considered that the basis should be the volume of sewage to be dealt with, but Mr. Baldwin Latham expressed the view that the area of land must be determined by the population draining to the farm, as indicating the strength of the sewage. The quality of the land itself must, of course, always be taken into account. Another factor to which importance was attached was the nature and extent of the preliminary treatment, if any, that the sewage receives before it is put on the land.

Scudder, 570. Santo Crimp, 1573. 4662-4. 4515-16.

Generally speaking, the evidence points to a maximum rate of 30,000 gallons per acre, or 1,000 persons per acre, with the best land, after preliminary treatment, although some witnesses put the rate as high as 60,000 gallons per acre, or 2,000 persons per acre, under similar conditions. With unsuitable land, such as clay, not more than 3,000 gallons per acre can be efficiently treated, even after settlement of the sewage.

Santo Crimp, 1571-2. Strachan, 7629-30. Roscoe, 3741 & 3744. Balfour, 6859-63.

Mr. R. A. Tatton handed in the following Table showing the approximate areas required with different soils :—

Tatton, 6578. 6578.

	Direct to Land.		After Precipitation or Mechanical Settlement.		After Filtration on Bacteria Beds.	
	Ratio of Population per Acre.	Acres per 1,000 Persons.	Ratio of Population per Acre.	Acres per 1,000 Persons.	Ratio of Population per Acre.	Acres per 1,000 Persons.
Broad Irrigation:						
Gravel	100	10	500	2	1,000	1
Light Loam	100	10	500	2	750	$1\frac{1}{3}$
Heavy Loam	75	$13\frac{1}{3}$	200	5	400	$2\frac{1}{2}$
Chalk	—	—	—	—	—	—
Peat	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.
Clay	50	20	100	10	300	$3\frac{1}{3}$
Intermittent Filtration:						
Gravel	150	$6\frac{2}{3}$	500	2	1,000	1
Light Loam	150	$6\frac{2}{3}$	500	2	1,000	1
Heavy Loam	75	$13\frac{1}{3}$	300	$3\frac{1}{3}$	500	2
Chalk	—	—	—	—	—	—
Peat	75	$13\frac{1}{3}$	200	5	400	$2\frac{1}{2}$
Clay	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.

196. With regard to the eight sewage farms which we had under our own observation, we give in the appended Table a statement of the nature and extent of the land, the volume dealt with, and a brief summary of our conclusions.

* *See* Vol. IV., part III., presented with our Fourth Report.

Name of Farm.	Nature of Sewage.	Nature of Soil and Subsoil.	Method of Treatment.	Area of Land under Treatment.	Volume treated per acre of land under treatment per 24 hours.	Population per acre of land under treatment.	Observations.
				Acres.	Gallons.		
Aldershot Camp	Domestic	Sand.	Screening, settling tanks and land filtration.	120½	8,300	166	The volume treated per acre was rather too large to yield effluents of the highest class, though the effluents showed a high percentage of purification. The sewage is exceptionally strong at Aldershot.
Altrincham	Domestic	Peaty soil, lying upon sand and gravel.	Settling tank and land filtration.	35	23,000	514	With a somewhat smaller volume of sewage per acre, probably the results would be distinctly good.
Cambridge	Mainly domestic	Sandy loam overlying gravel and sand.	Screening and settling tank and land filtration.	74	30,400	675	The effluents were usually good, but 30,400 gallons per acre was rather too large a volume to yield effluents of the highest class.
Croydon (Beddington) ...	Domestic	Gravelly loam over gravel and sand.	Screening and partly surface irrigation partly filtration.	420	9,500	238	With the method of treatment adopted 9,500 gallons per acre was too large a volume to yield an effluent of the highest class. If the 420 acres of land were laid out solely for filtration, no doubt a larger quantity of sewage could be treated per acre.
Leicester	¾ domestic; ¼ trade refuse	Stiff clayey soil overlying dense clay.	Screening, settling tanks, and surface irrigation and filtration combined.	1,350	5,370	146	The land was treating rather too large a volume per acre to yield effluents of the highest class.
South Norwood	Domestic	Clay soil resting on London clay.	Screening, settling tanks and surface irrigation.	152	4,000	138	The results indicated that rather too large a volume of sewage was put on the land to yield effluents of the highest class.
Nottingham	4/7 domestic, 3/7 trade refuse	Light sandy loam and gravel overlying gravel and sand.	Screening and land filtration.	651	10,750	397	The effluents were uniformly of exceptionally high quality, as judged by chemical analysis.
Rugby	Mainly domestic	Heavy loam overlying stiff clay.	Screening, chemical precipitation, settling tanks, and surface irrigation and filtration combined.	35	8,500	171	The volume treated on the land per acre was too large to yield effluents of the highest class.

197. It will be seen that, at Nottingham, where the soil is well adapted for the purification of sewage, the volume of sewage treated per acre was only 10,750 gallons. The results were exceptionally good, and there is little doubt that a larger volume could have been efficiently purified. At Cambridge, which has the same kind of soil and subsoil, the volume treated per acre, viz., 30,400 gallons, proved rather too large to yield an effluent of the highest class. Taking the two places together, the results may perhaps be regarded as supporting the evidence of witnesses that sewage can be treated at the rate of 30,000 gallons per acre per day on the best soils.

In other cases, where the soil is of a heavy nature and not so well adapted for the purification of sewage, the results again seem to corroborate the views of witnesses as to the volume which can be dealt with on unsuitable soils, viz., not more than 3,000 gallons per acre per 24 hours, if a good effluent has to be produced.

The total acreage of a farm must be relatively much greater when the sewage is purified by surface irrigation than when the method of filtration is employed, and a larger percentage surplus area is also desirable in the former case. We are not able to lay down any rule as to what the ratio of surplus acreage to total acreage should be, but generally speaking, a large surplus area is advisable.

It is true that the larger the total irrigable area, the greater is likely to be the working cost. On the other hand, with good management, the larger the surplus irrigable area, the better is the purification likely to be and—within certain limits—the prospect of profit.

198. The following Tables D, E, F, have been compiled, with a view to showing in some detail, the amount of purification work which was done, per unit area, at the farms which we had under observation.

The figures for strength of sewage, strength of effluent, and units of purification are arrived at on the bases already explained.

TABLE D.

Name of Farm.	Population per acre of land under treatment.	Relative figures of population per acre of land under treatment.	Gallons of sewage treated per acre of land under treatment, per day.	Gallons of sewage treated per square yard of land under treatment, per day.	Relative figures.	Relative oxidizable matter treated per square yard (*i.e.*, gallons per square yard "strength" figure for sewage).	Relative figures.	Ratio of oxidizable matter treated per unit area to volume treated per unit area.	Gallons of sewage per head per day.
Cambridge - - - -	675	100	30,400	6·28	100	666	100	1 : 9·4	45
Altrincham - - - -	514	76	23,000	4·75	76	259 (?)	39 (?)	—	44
Nottingham - - - -	397	59	10,750	2·22	35	404	61	1 : 5·5	27
Beddington - - - -	238	35	9,500	1·96	30	218	33	1 : 9·0	40
Rugby - - - - -	171	25	8,500	1·76	28	296	46	1 : 5·8	50
Aldershot Camp - - -	166	25	8,300	1·72	27	332	50	1 : 5·2	50
Leicester - - - - -	146	22	5,370	1·11	18	180	28	1 : 5·9	37
South Norwood - - - -	138	20	4,000	0·83	13	61	9	1 : 13·7	29

TABLE E.

Name of Farm.	Gallons of sewage treated per square yard of land under treatment per day.	"Strength" of Sewage.	"Strength" or oxidizability of effluent (including the nitrate).	Parts by weight of oxygen used in oxidizing 100,000 parts of sewage (including the oxygen required to produce the nitrate of the effluent).	"Units of purification" effected per square yard.	Average depth to drains.	"Units of purification" effected per cube yard.	Percentage purification calculated on "Oxygen absorbed" in 4 hours from permanganate (chance effluents compared with hourly sewages).
Cambridge - - - - - -	6·28	106 (2)	0·0	106	666	4 ft. 6 in.	381	92 per cent.
Altrincham - - - - - -	4·75	54·5 ? (1)	4·4	50·1	238	3 ft. 9 in.	190	?
Nottingham - - - - - -	2·22	182	— 5·0	187	415	7 ft. 0 in.	178	99
Beddington - - - - - -	1·96	111	6·7	104·3	204	2 ft. 3 in.	272	89
Rugby - - - - - -	1·76	168	7·4	160·6	283	Say 2 ft. 0 in.		92
Aldershot Camp - - - - -	1·72	193	1·0	192	330	3 ft. 3 in.	305	87
Leicester - - - - - -	1·11	168 (2)	8·0	160	178			88
South Norwood - - - - -	0·83	73	3·6	69·4	57·6			81

(1.) ALTRINCHAM.—In this case the "strength" is calculated from 4 *chance* samples of sewage plus 5 *chance* samples of lagoon liquor. The figure for "strength" is therefore not nearly reliable as in the other cases; probably it is considerably below the truth.

(2.) Making correction for abnormal ratio between "oxygen absorbed" from permanganate *at once* and *in* 4 *hours* in the cases of Cambridge and Leicester.

TABLE F.

Name of Farm.	(*a*) Sewage treated.	(*b*) Gallons per acre of land under treatment, per 24 hours ÷ 1,000	(*c*) Calculated strength of sewage.	(*d*) Relative oxidizable matter treated on unit area (b × c).	(*e*) Population per acre of land under treatment.	(*f*) Relative oxidizable matter treated per head of population (d ÷ e).
Cambridge - - -	Screened and settled.	30·4	106	3,222	675	4·8
Altrincham - -	Very well settled in lagoons.	23·0				
Nottingham - -	Screened and crude.	10·8	182	1,966	397	5·0
Beddington - -	Screened and settled.	9·5	111	1,055	238	4·4
Rugby - - -	Screened and settled.	8·8	168	1,478	171	8·6
Aldershot Camp - -	Screened and settled.	8·3	193	1,602	166	9·0
Leicester - - -	Screened and settled.	5·7	168	908	146	6·2
South Norwood - -	Screened and settled.	4·0	73	292	191	1·5

The figures in column (*f*) for relative oxidizable matter per head shew marked divergences, but still, if we except South Norwood, where the figure is probably below the truth, the extreme limits are only 4·4 and 9 or 1 : 2. The highest figures occur at Aldershot Camp and Rugby, where the sewages (domestic) are very strong.

199. The following points are brought out by these Tables :—

The *relative* figures for population per acre irrigated, and for gallons per day, follow one another pretty closely, excepting in the case of Nottingham.

The *relative* oxidizable matter per head of population varied from about 1 to 2. It was greatest in the stronger sewages.

The *relative* "strength" of the sewage per gallon, *i.e.*, oxidizable matter per gallon, varied roughly from 1 to $2\frac{1}{2}$, but it was nearly constant for the less strong sewages.

The volumes of sewage (screened and settled in nearly every case) treated per 24 hours at the different farms ranged between 0·83 and 6·28 gallons per square yard, or between 4,000 and 30,400 gallons per acre.

200. The quantity of sewage which can be treated upon an unit area of land is necessarily small, because of the fineness of the filtering medium. Apart from this it is dependent upon a number of factors, of which the principal are :—

(*a*) Whether surface irrigation or filtration is followed.

(*b*) The quality and depth of the soil and subsoil.

(*c*) Whether or not the land is cropped.
(*d*) The strength of the sewage or sewage liquor.
(*e*) The degree of clarification of the liquor.

We have had no opportunity of ascertaining, quantitatively, whether it is easier with land treatment to purify one volume of strong sewage, or two volumes of a sewage of half the strength. We should infer, however, that the results with land would be so far analogous to those with artificial filters that, within ordinary limits of strength of sewage, *and so long as water-logging of the land was avoided*, there would be no appreciable difference in purification in the two cases. Since, however, a fine filtering medium like soil readily tends to become clogged on the surface, and, therefore, becomes sodden sooner than the relatively coarse medium of artificial filters, we think it would generally be found easier to treat upon land one volume of a strong sewage rather than two volumes of a sewage of half the strength, and that, therefore, with land treatment, the volume of liquid to be dealt with is of greater consequence than its actual strength.

Physical Texture of Soils.

201. A detailed account of the mechanical analyses of the soils and subsoils of the principal farms under observation is to be found in Volume IV., Part II., presented with our Fourth Report.* The results of these mechanical analyses, while too few to allow of general deductions being drawn, show that it is possible to say from the mechanical analysis of a soil whether or not it would be suitable for purifying sewage by filtration, and the same statement holds true, though in a lesser degree, as regards suitability for surface irrigation.

Preliminary Settlement of Sewage before Land Treatment.

202. In the case of sewage which is to be treated upon artificial filters, it is generally desirable to settle out as much of the suspended solids of the sewage as possible before filtration. This is of less moment in the case of land, but where the soil is heavy we think that the sewage should usually be efficiently screened and settled. Porous sandy soils, worked as filtration farms, may be able to treat crude unsettled domestic sewage without detriment, but, even in those cases, there is the possibility of nuisance arising from the decomposition of sewage solids on the surface of the soil, and such solids may cause damage to crops.

Disposal of Sludge at Sewage Farms.

203. At a sewage farm the disposal of the sludge offers no particular difficulty, the land treatment of sewage possessing in this respect a great natural advantage over artificial treatment.

The question of the disposal of sludge generally is dealt with in a later section.

Evaporation and Absorption of the Water of Sewage in Land Treatment.

204. In the artificial filtration of sewage or sewage liquor, practically all the sewage which flows on to the filter appears as effluent, very little evaporation taking place. In the case of land purification, however, especially where crops are grown, the liquid is partly absorbed by the plant and partly evaporated, and consequently, the volume of the resulting effluent is materially less than that of the original sewage. Indeed, in warm weather, very little effluent passes away from surface irrigation farms treating moderate volumes of sewage.

Loss of Nitrogen from Sewage during its Purification.

205. The most important manurial constituent of sewage is the ammonia which is produced by the fermentation of the urea of the urine, but it also contains organic nitrogen

* Mechanical Analysis of Soils and Subsoils. By G. McGowan and R. S. Finlow.

compounds in smaller quantity, together with phosphates and salts of potash. In the process of sewage purification by artificial filtration, varying quantities of the nitrogen of the ammonia and other compounds disappear, partly, no doubt, from conversion into gaseous nitrogen, and partly from being assimilated by vegetable growths, worms, flies, etc.; the remainder of the nitrogen is converted (in a well purified effluent) into nitrate. The following average figures, obtained from our own work, may be taken as giving a fair idea of the amounts of nitrogen which disappear during the treatment of sewage and sewage liquors upon contact beds and percolating filters, and upon land. In the latter case, much of the nitrogen which has vanished has been used up by growing crops.

	Percentage of the Nitrogen of Sewage or Sewage Liquor which disappears during the Process of Purification.
Land Surface Irrigation of Sewage - - - - -	About 60 (40 to 75).
Land Filtration of Sewage - - - - - -	
Treatment of Sewage on Percolating Filters - - -	40 to 50.
„ Septic Liquor on Contact Beds - - -	40 to 45 Single Contact. 40 to 50 Double Contact.
„ Septic Liquor on Percolating Filters - -	30 to 40 or less.
„ Precipitation Liquor on Contact Beds - -	25 (Single Contact.)*
„ Precipitation Liquor on Percolating Filters -	40 to 50.

206. It is in the form of nitrate that nitrogen is taken up by most plants. Much has been written about the loss to the country arising from the non-utilisation of the nitrogen of sewage which has been purified by artificial filtration, a loss which is certainly to be deplored. It is, however, frequently forgotten that when water-borne sewage is purified on land, upon which grass or other crops are grown, loss of nitrogen is, to a large extent, unavoidable in the colder seasons of the year, since plants can only assimilate nitrate very slowly in cold weather. As regards the production of nitrate in the soil, it is well known that this is largely influenced by temperature, coming practically to a standstill when the temperature is very low, but it is probable, we think, that in this country the temperature would very rarely be sufficiently low for a long period, to arrest nitrification. During our observations on sewage farms, we had no experience of a very severe winter, but nitrification was not materially hindered by such cold as we did experience. It will, of course, be remembered, in this connection, that the temperature of sewage itself is comparatively high.

In Vol. IV., Part IV., of the Report to the Commission upon Land Treatment (Engineering and Practical), by Mr. Kershaw, are diagrams giving the daily temperatures, over a year, of air, sewage, and effluent at the sewage farms of Nottingham, Aldershot Camp, South Norwood, and Beddington. On only one occasion during the winter of 1900–1 did the temperature of the sewage at Nottingham fall below 50° F., while the lowest temperatures for sewage at other farms were 46° F. at Beddington, 42° F. at South Norwood, and 40° F. at Aldershot Camp. The diagrams also show the equalising effect, as regards temperature of effluent, of the filtration farms, Aldershot Camp and Nottingham, while in the case of the surface irrigation farms of Beddington and South Norwood, the temperature of the effluent follows that of the air pretty closely.

There is, unfortunately, no economical method of extracting the nitrate from a sewage effluent otherwise than through the agency of plants, and, as we have stated, there must of necessity be a considerable loss of valuable nitrogenous manure from water-borne sewage, even in the case of land purification. In the case of artificial filtration, supposing

* This figure is from one installation only.

the effluent to be subsequently discharged into a stream, the loss is, of course, much greater, all the manurial constituents of the sewage, apart from those in the sludge, being wasted. They will, it is true, augment the vegetable growths in the stream itself, but this is nearly always more or less objectionable.

Is a Sewage Farm Dangerous to Health?

207. No proof has yet been furnished of direct or wide-spread injury to health, in the case of well-managed sewage farms. It is interesting to note here that the Report for 1905 on the sewage farm of Berlin contains the following statement :—

"We can only repeat here what we have said in previous Reports—that the sewage treatment (*Rieselbetrieb*) has had no injurious effect upon health."

This farm covers an area of nearly 39,000 acres of sandy soil, and there was on the ground in 1905 a resident population of 4,198 persons.

Wells in the Neighbourhood of Sewage Farms.

208. We have examined too few samples of well water in the neighbourhood of sewage farms to allow of our drawing any safe conclusions, on experimental grounds, as to the admissibility of such wells. But on general grounds, and quite apart from any scientific data, it would seem to be unsafe to sink any shallow wells in the neighbourhood of sewage farms, or to use water for domestic purposes from any such existing wells, unless the evidence as to the safety of the water were of a most convincing kind.

Deep wells sunk through an impermeable stratum are probably safe in the majority of instances, but wells not protected in this way, and sunk through fissured strata, can not be relied on to yield a safe water supply, however deep they may be.

Chalk wells are, perhaps, the most dangerous in this respect, and a recent Report by Dr. Copeman on an outbreak of enteric fever at Fulbourn Asylum,* and a paper † read at a recent meeting of the Epidemiological Society by Drs. Richards and Brinker, serve to confirm this view in a striking manner. The latter mention that a culture of a special organism was poured into a "swallow" hole at a distance of about two miles from the well, and was recovered from the well water after 67½ hours. It is doubtful whether sewage farms on chalk should be permitted without wide knowledge of the trend of underground water in relation to water supplies.

An attempt was made to collect an effluent on the Luton farm by digging a pit in the chalk, and in this way a few samples were obtained. The results, so far as they went, showed that *apart from the purification effected by the surface soil*, sewage underwent comparatively little purification in its passage through about three feet of chalk.

Sewage Farms on Peat Land.

209. Peat being of the nature of a sponge is not suitable for sewage purification, because of the difficulty of draining it, and the consequent lack of aeration. Some observations were made at the Worsley Sewage Farm, part of which is on peat land, and the results obtained there bear out this statement. The details of these observations are to be found in Vol. IV., Parts I. to IV., presented with our Fourth Report.

Management of Sewage Farms.

210. It is impossible to lay too much stress on the importance of sewage farms being well managed. In this connection it has to be borne in mind that farm managers have a most difficult part to play, and no amount of care and attention will ever enable land, of any kind, to deal with a volume of sewage which is in excess of the effective purifying area of the soil. We think it would be useful that farm managers should be taught some simple test or tests to enable them to follow the operations of the land; that their instructions should include a definite order to consider the farming results as quite secondary to the production of an effluent of the required standard; that the statistics of the farm should be carefully kept; and that, wherever possible, the flow of sewage and storm water should be gauged throughout the year.

As a general rule, we consider that sewage farms should not be let.

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* Report of the Medical Officer, Local Government Board, 1905–6, Appendix A., No. 6, pp. 146–169.
† The Potential Danger of Water derived from Wells in the Chalk.

Some Observations as to the Cost of Land Treatment of Sewage.

211. The cost of land treatment, as in the case of artificial filtration, varies with local conditions, and no figures can be given which would be generally applicable. In Table I. we give the annual cost per 1,000,000 gallons and per head for the eight sewage farms which we had under our own observation for over two years. In each case, the cost per 1,000,000 gallons is based upon the dry weather flow of sewage. The actual flow, however, included large volumes of storm water in most cases.

Table I.

Farms which were under continuous observation by officers of the Commission for over two years.

Place.	Population draining to farm.	Dry weather flow of sewage in gallons per 24 hours.	Net cost of treating the sewage per million gallons (including loan charges), based on the dry weather flow.	Net annual cost of treatment per head of population draining to farm, including loan charges.
		Gallons.	£ s. d.	s. d.
South Norwood -	21,000	600,000	*15 9 7	*3 $2\frac{1}{2}$
Leicester - - -	197,000	7,250,000	5 12 $8\frac{1}{2}$	1 6
Croydon (Beddington)	100,000	4,000,000	5 7 $5\frac{3}{4}$	1 $6\frac{3}{4}$
Cambridge - -	50,000	2,250,000	2 5 $5\frac{3}{4}$	0 9
Aldershot Camp -	20,000	1,000,000	†1 18 4	†0 $8\frac{1}{4}$
Rugby (High Level)	6,000	300,000	1 9 $8\frac{1}{2}$	0 $6\frac{1}{4}$
Altrincham - -	18,000	800,000	1 3 $3\frac{3}{4}$	0 $4\frac{1}{4}$
Nottingham - -	258,000	7,000,000	The figures of cost cannot be given for Nottingham. Excluding loan charges, cost of pumping, and rent of farm, however, there is usually a small profit on the year's working of the farm, which covers the cost of labour and also part of the rent.	

212. With a view to making some comparison between the cost of land treatment and the cost of treatment by "artificial" processes, we have thought it useful to work out the cost of treating on land a dry weather flow of 1,000,000 gallons a day, in certain hypothetical cases, following the plan adopted in regard to filters.

It is assumed for the purpose of this comparison :—

That, in the case of surface irrigation, sufficient fall is available, and that, in the case of filtration, the land is fairly level, admitting of its being used without abnormal expenditure in levelling and grading.

That the sewage to be treated is of a normal domestic character and of average strength (*i.e.*, gives a *four hours* "oxygen absorbed" figure of 10 to 12 with strong permanganate, and requires about 100 parts by weight of oxygen for the complete oxidation of 100,000 parts).

That the flow of sewage is one million gallons per day in dry weather.

That the district is sewered on the combined or the partially separate system.

That the cost of the land is £100 per acre.

*These figures include cost of pumping the effluent from the lower to the higher portions of the farm.

† No loan charges in the case of Aldershot Camp.

The soils and subsoils which we have considered, may be divided into the following three broad classes :—

Class I. All kinds of good soil and subsoil, *e.g.*, sandy loam overlying gravel and sand as at Nottingham, Cambridge, and Beddington.

Class II. Heavy soil overlying clay subsoil, as at Rugby.

Class III. Stiff clayey soil overlying dense clay, as at Leicester and South Norwood.

Since variations exist in practice, both as regards the method of purification employed and the extent of cropping, the first of these three classes may be divided into three sub-classes, as follows :—

Class I.
- Sub-class a. Filtration with cropping.
- Sub-class b. Filtration with little cropping.
- Sub-class c. Surface Irrigation with cropping.

The method of purification assumed for the other classes of soil are :—

Class II. Surface Irrigation with cropping.

Class III. Surface Irrigation with cropping. With a heavy soil and clay subsoil, by far the greater part of the purification is effected by surface irrigation, though in exceptional circumstances, such as obtain at Leicester, a good deal is also done by filtration.

213. Having regard to the volume of sewage dealt with and the purification effected at the farms which were kept under our own observation, and the evidence given by various witnesses, we estimate that the several classes of soil and subsoil could effectively deal with the volumes of settled sewage given in Table II.

TABLE II.

Class of soil and subsoil, and method of working.	Volume of settled sewage which can be dealt with per acre per 24 hours.	Total area of land required to deal with a dry weather flow of one million gallons.*
Class I. Sub-class a. Filtration with cropping	12,000 gallons	84 acres
Class I. Sub-class b. Filtration with little cropping	25,000 gallons	40 acres
Class I. Sub-class c. Surface irrigation with cropping	7,000 gallons	145 acres
Class II. Surface irrigation with cropping	5,000 gallons	200 acres
Class III. Surface irrigation with cropping	3,000 gallons	334 acres

* These areas are sufficient for the treatment in times of storm water of three times the mean dry weather flow.

Preliminary Tank Treatment.

214. At many of the sewage farms named in Table I. there is no preliminary settlement of the sewage, while at some of them the preliminary process does not secure anything like complete removal of the suspended matter.

For the purpose of our comparison, however, we have assumed preliminary settlement of the sewage in tanks of the capacities indicated in Table III:—

TABLE III.

Class of soil and subsoil and method of working.	Average stay in tanks.	Total number of tanks.	Number of spare tanks.	Total capacity of tanks (gallons)	Constructional cost of tanks.*
Class I. Sub-class a. Filtration with cropping	4½ hours	4	1	250,000	£2,230
Class I. Sub-class b. Filtration with little cropping	4½ hours	4	1	250,000	£2,230
Class I. Sub-class c. Surface irrigation with cropping	4½ hours	4	1	250,000	£2,230
Class II. Surface irrigation with cropping	15 hours	8	2	833,333	£5,112
Class III. Surface irrigation with cropping	15 hours	8	2	833,333	£5,112

* The estimates of the constructional cost of tanks are strictly comparable with the estimates for similar plant in connection with the artificial processes, and have been obtained by preparing drawings and taking out quantities.

Cost of Preliminary Tank Treatment and Disposal of Sludge.

215. We estimate that the working of the tanks and the disposal of the sludge, including trenching the land and covering the sludge, would require the services of two men for each of the first three classes (4½ hours sedimentation), and the services of three men for the other two (15 hours sedimentation).

Taking labourers' time at 21s. per week, and including one-third of the manager's time at a salary of £130 per annum, the following figures are obtained:—

TABLE IV.

Class of soil and subsoil and method of working.	Labour and supervision in connection with tanks and disposal of sludge.	
	Per annum.	Per million gallons of sewage (dry weather flow).
	£	s. d.
Class I. Sub-class a. Filtration with cropping	152	8 4
Class I. Sub-class b. Filtration with little cropping	152	8 4
Class I. Sub-class c. Surface irrigation with cropping	152	8 4
Class II. Surface irrigation with cropping	208	11 5
Class III. Surface irrigation with cropping	208	11 5

In the case of Classes II. and III. (heavy soils and subsoils), it would generally be advisable to eliminate the suspended solids from the sewage to a greater extent than in the other class where the soil and subsoil are of good quality.

With an average domestic sewage, the suspended solids after 4½ hours settlement (continuous flow) would be about 20 to 25 parts per 100,000, and, after a 15 hours settlement (continuous flow), from 10 to 15 parts per 100,000.

Converting these amounts of suspended solids into tons of wet sludge per million gallons, the quantities of sludge to be disposed of are approximately as follows :—

TABLE V.

Class of soil and subsoil and method of working.	Wet sludge (90% water) produced per million gallons from the average daily flow.	Area of land estimated to be required for disposal of the sludge.
Class I. Sub-class a. Filtration with cropping	8 to 10 tons	5 acres
Class I. Sub-class b. Filtration with little cropping	8 to 10 tons	5 acres
Class I. Sub-class c. Surface irrigation with cropping	8 to 10 tons	5 acres
Class II. Surface irrigation with cropping	17 to 20 tons	12 acres
Class III. Surface irrigation with cropping	17 to 20 tons	20 acres

Table VI. shows the total areas of land required for treatment of the sewage and for disposal of the sludge, and the total cost of land and tanks.

TABLE VI.

Class of soil and subsoil.	Total area of land required to treat a dry weather flow of one million gallons.	Area of land required for disposal of sludge.	Total area.	Total cost of land at £100 per acre.	Cost of laying out land, including levelling, grading, underdrains, carriers, etc.	Cost of tanks.	Total cost.
				£	£	£	£
Class I. Sub-class a	84 acres	5 acres	89 acres	8,900	6,334	2,230	17,464
Class I. Sub-class b	40 acres	5 acres	45 acres	4,500	4,589	2,230	11,319
Class I. Sub-class c	145 acres	5 acres	150 acres	15,000	4,494	2,230	21,724
Class II.	200 acres	12 acres	212 acres	21,000	5,770	5,112	32,082
Class III.	334 acres	20 acres	354 acres	35,400	7,599	5,112	48,111

216. With regard to the underdraining of land, the necessity for drains depends not merely upon the nature of the soil and subsoil, but upon the volume of liquid dealt with per acre. A porous soil and subsoil like that at Beddington can be made to answer perfectly well without underdrains, when a moderate volume of sewage is applied; when, however, a large volume is applied, underdrains are necessary, in order to assist the land to "dry-off" sufficiently rapidly.

In Sub-class a (Class I.), we have assumed that the tributary drains average 6 feet in depth and are laid 66 feet apart.

In Sub-class b (Class I.), where the volume of liquid applied is larger, and the area proportionately less, the tributary drains, also 6 feet deep, have been placed 50 feet apart.

In the case of the surface irrigation farms (Sub-class c and Classes II. and III.), underdrainage has been allowed for, to provide for the contingency of possible over sewaging of the plots; but in the case of the heavy soils and subsoils we have assumed that the drains are only laid at a depth of 2 feet 6 inches and that they are brought to the surface of the ground to admit of re-treatment of the effluent by surface irrigation.

Loan Charges.

217. Table VII. gives the loan charges in respect of cost of land, tanks, etc., on the basis of loans raised for thirty years, at 3½ per cent. interest per annum.

TABLE VII.

Class of soil and subsoil and method of working.	Loan charges in respect of land, tanks, laying out land, underdrains, etc.	
	Per annum.	Per million gallons of sewage. (dry weather flow).
	£ s. d.	£ s. d.
Class I. Sub class a. Filtration with cropping	949 12 1	2 12 0
Class I. Sub-class b. Filtration with little cropping	615 9 5	1 13 8¾
Class I. Sub-class c. Surface irrigation with cropping	1,181 4 10	3 4 8¾
Class II. Surface irrigation with cropping	1,744 9 2	4 15 7
Class III. Surface irrigation with cropping	2,616 0 8	7 3 4

Labour in connection with the Distribution of the Sewage.

218. The number of men required in connection with the distribution of the sewage, etc., must of course depend largely upon the nature and contour of the lands sewaged, and upon the nature of the crops raised, whether stock is kept, etc.

From numerous examples of land treatment, however, we find that roughly speaking one man can attend to the distribution of the sewage over about 40 acres.

It has been assumed in the present comparison that the services of the men who undertake the sludging of the tanks are available, and we estimate that in addition to these men the number of watermen required would be as follows :

TABLE VIII.

Class of soil and subsoil and method of working.	Number of watermen required.
Class I. Sub-class a. Filtration with cropping	One.
Class I. Sub-class b. Filtration with little cropping	One.
Class I. Sub-class c. Surface irrigation with cropping	Two.
Class II. Surface irrigation with cropping	Three.
Class III. Surface irrigation with cropping	Four

Taking labourers' wages as before at 21s. per week, together with two-thirds the manager's time, the cost of labour and supervision in respect of the distribution of sewage is as follows :—

TABLE IX.

Class of soil and subsoil and method of working.	Cost of labour and supervision in respect of distribution of sewage.	
	Per annum.	Per million gallons (dry weather flow).
	£	£ s. d.
Class I. Sub-class a. Filtration with cropping	141	0 7 8¾
Class I. Sub-class b. Filtration with little cropping	141	0 7 8¾
Class I. Sub-class c. Surface irrigation with cropping	196	0 10 9
Class II. Surface irrigation with cropping	250	0 13 8½
Class III. Surface irrigation with cropping	305	0 16 8½

219. The total cost of treatment, including loan charges and all other charges, is shown in Table X.

Table X.

Total Gross Cost of Land Treatment.

Class of soil and subsoil and method of working.	Per annum.	Per million gallons (dry weather flow).
	£ s. d.	£ s. d.
Class I. Sub-class a. Filtration with cropping	1,242 12 1	3 8 0¾
Class I. Sub-class b. Filtration with little cropping	908 9 5	2 9 9
Class I. Sub-class c. Surface irrigation with cropping	1,529 4 10	4 3 9¾
Class II. Surface irrigation with cropping	2,202 9 2	6 0 8½
Class III. Surface irrigation with cropping	3,129 0 8	8 11 5½

Returns from Sales of Crops.

220. In the case of land treatment of sewage, a part, frequently a large part, of the cost of treatment is defrayed by returns from sales of crops, stock, sludge, etc.

These returns necessarily vary at different farms, but we find from a careful study of the figures obtained at thirteen sewage farms, that the net return, after deducting cost of agricultural working, may be put at about 30s. per acre of the total area of the farm. We have therefore taken this figure for our calculations in the following Table :—

Table XI.

Class of soil and subsoil and method of working.	Returns from sales of crops.	
	Per annum.	Per million gallons (dry weather flow).
	£ s. d.	£ s. d.
Class I. Sub class a. Filtration with cropping	126 0 0	0 6 10¾
Class I. Sub-class b. Filtration with little cropping	60 0 0	0 3 3¼
Class I. Sub-class c. Surface irrigation with cropping	217 10 0	0 11 11
Class II. Surface irrigation with cropping	300 0 0	0 16 5
Class III. Surface irrigation with cropping	501 0 0	1 7 5

Total net Cost of Treatment.

221. Deducting the returns from sales of crops from the gross cost of treatment, we obtain the following figures for the total net cost of treatment :—

Table XII.

Class of soil and subsoil and method of working.	Net cost of treatment.	
	Per annum.	Per million gallons.
	£ s. d.	£ s. d.
Class I. Sub-class a. Filtration with cropping	1,116 12 1	3 1 2
Class I. Sub class b. Filtration with little cropping	848 9 5	2 6 6
Class I. Sub-class c. Surface irrigation with cropping	1,311 14 10	3 11 10¾
Class II. Surface irrigation with cropping	1,902 9 2	5 4 3
Class III. Surface irrigation with cropping	2,628 0 8	7 4 0

Comparative Cost of Treatment of Sewage by Land and by Artificial Processes.

222. Table XIII. shows the comparative cost of treatment of sewage by land and by artificial processes.

We wish to emphasize the fact that in the preparation of our "cost" tables, we have made a number of assumptions. and that the relative cost of different methods would, in practice, largely depend on local circumstances.

Table XIII.

Method of Treatment.	Total cost of treatment per annum.	Total cost of treatment per million gallons.	*Cost per head of population draining to works (population taken at 30,000).
	Percolating Filters.		
Chemical precipitation, quiescent settlement, followed by percolating filters.	£ s. d. 1,831 0 4	£ s. d. 5 0 4	s. d. 1 2½
Chemical precipitation, continuous flow settlement, followed by percolating filters.	1,796 11 2	4 18 5	1 2¼
Quiescent settlement, followed by percolating filters.	1,490 16 11	4 1 7	0 11¾
Continuous flow settlement, followed by percolating filters.	1,525 1 1	4 3 7	1 0
Septic Tanks, followed by percolating filters -	1,589 13 4	4 7 2	1 0½
	Contact Beds.		
Chemical precipitation, quiescent settlement, followed by single contact beds.	2,058 16 11	5 12 10	1 4¼
Chemical precipitation, continuous flow settlement, followed by double contact beds.	2,314 12 5	6 6 9	1 6½
Quiescent settlement, followed by double contact beds.	2,393 0 7	6 11 4	1 7
Continuous flow settlement, followed by double contact beds.	2,596 17 3	7 2 3	1 9
Septic Tanks, followed by double contact beds -	2,661 9 6	7 5 10	1 9¼
Class of soil and subsoil and method of working.	Land Treatment.		
Class I. Sub-class a. Filtration with cropping	1,116 12 1	3 1 2	0 8¾
Class I. Sub-class b. Filtration with little cropping	848 9 5	2 6 6	0 6¾
Class I. Sub-class c. Surface irrigation with cropping	1,311 14 10	3 11 10¾	0 10½
Class II. Surface irrigation with cropping - -	1,902 9 2	5 4 3	1 3¼
Class III. Surface irrigation with cropping -	2,628 0 8	7 4 0	1 9

*Based on a flow of 33 gallons of sewage per head per day.

Assuming that really suitable land can be purchased at £100 per acre, land treatment of sewage is probably cheaper than artificial treatment, but where the soil is not suitable, and on which only a comparatively small volume of sewage can be treated per acre, the cost of land treatment would probably be greater than most of the artificial processes.

The differences in cost are, however, small, and it is evident that, in deciding between the two methods, regard must be had to local conditions. If, for instance, £200 per acre had to be paid for land, the cost of land treatment would materially exceed the estimates given, which have been based on an assumed uniform price of £100 per acre.

As a general rule an effluent from good land, properly worked, contains practically no suspended solids, but this cannot be said of artificial filters, even assuming that settlement of the effluent in tanks is adopted. This might be a factor of considerable importance in the case of some streams.

The figures of cost in this section have been prepared by our Engineer, Mr. G. B. Kershaw.

PART IV.—SLUDGE.

DISPOSAL OF SEWAGE SLUDGE.

223. The disposal of sewage sludge, whether it is produced by settlement after chemical precipitation, settlement without chemicals, or septic tank treatment, is one of the chief difficulties in dealing with sewage, especially in the case of large towns or cities. Probably it will always remain so, excepting at small sewage works, for although sewage sludge contains small quantities of nitrogenous compounds and phosphates, and sometimes grease in sufficient quantity to repay extraction, by far the greater part of it consists, in addition to moisture, of mineral matters, together with some cellulose.

Conversion of Sludge into a Marketable Manure.

224. Two processes for converting sludge into a marketable manure have been under observation by us, viz.:—the production of "Native Guano" by the Native Guano Company, Limited, at Kingston-on-Thames, and the production of "Globe Fertilizer" by Mr. Melvin's process at Glasgow.

Kingston-on-Thames.

At Kingston a quantity of alumino-ferric, together with blood, charcoal, and clay is added to the sewage. This mixture acts as an extremely efficient precipitant, producing uniformly, from a sewage of about average strength, a tank liquor containing seldom more than two parts of suspended matter per 100,000. The sludge is removed from the tanks, pressed, partially dried by heat and sieved, and, after further air-drying during storage, is sold under the name of "Native Guano." The cost to the inhabitants of Kingston of the precipitation of the sewage and the disposal of the sludge * is 1s. 8d. per head per year. This is considerably less than it would be if a less expensive precipitation process were adopted and the sludge barged to sea. Further, although there is generally a slight peculiar odour of Native Guano upon the works, the treatment, so far we have observed it, has been free from nuisance.

It will be seen from the manurial experiments with sewage sludges, which are referred to later, and which were carried out for the Commission through the Board of Agriculture and the Royal Agricultural Society, during the seasons 1905–7,† that unit for unit the nitrogen and phosphate of the Native Guano were less effective, at all events within the limits of one season, than the same constituents applied in the form of ordinary artificial manure. Judged solely in this light, the price of the Native Guano is in excess of its direct manurial value. On the other hand, the books of the Company show that the manure is sold to the same farmers year by year. The manure appears to be used to a considerable extent for flower culture.

We doubt whether the process could be worked as a financial success if it were adopted at a *large* number of places, as, apart from the considerations which have just been mentioned, a greatly increased production of the manure would, we think, be certain to lower the price considerably.

It should be added, however, that the cost of the precipitation, and possibly also of other parts of the manufacture of the Native Guano, might, we think, be materially reduced by working on a large scale.

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* This constituted the whole process at Kingston during the greater part of our observations. The figure 1s. 8d. per head refers to the precipitation and sludge disposal only. The precipitation liquor is now (1907) treated upon filters.

† Reports upon Experiments with various kinds of Sewage Sludges, as applied to mangolds, grass and cereals, by Dr. W. Somerville (1906), Mr. T. H. Middleton (1907), and Dr. J. A. Voelcker (1907), Appendix VIII.

A sample of Native Guano (A.), made up of eighty-five different fractions, was taken on March 23rd, 1905, and examined both chemically and bacteriologically. It was in a fine state of division. In the second column are given the figures of analysis of another sample of Native Guano (B.), examined partly in October, 1904, and partly in January, 1905. The following results were obtained :—

	A. Per cent.	B. Per cent.
Moisture (at about 110° C.)	25·87	10·19
Matter volatile on ignition	37·99	45·08
Non-volatile matter	36·14	44·73
	100·0	100·0

Analysis of Non-Volatile Matter.

	Per cent.	Per cent.
Grit (*i.e.*, matter insoluble in hydrochloric acid, after ignition)	22·33	28·04
Oxides of iron and alumina*	10·10	11·59
Lime†	3·30	4·78
Magnesia		0·42
Potash (soluble in dilute hydrochloric acid)	approx. 0·16	—
Potash (soluble in water)	0·06	—
Phosphoric acid (P_2O_5)	1·74§	2·35§
Equivalent to tribasic phosphate of lime	3·30	5·13
Yield of Nitrogen (total)	1·93‖	2·49‖
Nitrogen evolved as ammonia on boiling for 2 hours with a dilute solution of potash (0·5 per cent. KOH)	0·41	0·50

Allowing for the difference in moisture, the above two samples have almost the same composition, but B. is slightly richer in nitrogen and phosphoric acid than A.

Bacteriological Analysis.—Sample A.

Kingston "Native Guano." Average of eighty-five samples, March 23rd, 1905.

B. Coli Test.—Negative result with 1 gramme.

Neutral Red Broth Test.—As regards fluorescence, positive with 1–1,000 ; negative with 1–10,000 of a gramme. Growth in tube inoculated with 1–10,000,000,000 of a gramme, indicating the survival of an enormous number of bacteria.

B. Enteritidis Sporogenes Test.—Positive result with 1–1,000 ; negative with 1–10,000 of a gramme.

Glasgow (Dalmarnock).

225. Mr. Melvin's process at Glasgow for the production of the "Globe Fertiliser" is somewhat similar to the process for the production of Native Guano. The sludge is produced from the Glasgow (Dalmarnock) sewage by precipitation with lime and ferric sulphate. After removal from the tanks it is pressed, and that part of it which is to be converted into Globe Fertiliser is then artificially dried at a temperature of about 65° to 70° C., and finally passed through a pan-mill. It issues from the latter as a moist brown powder, which is given the name of "Globe Fertiliser." An average sample of this, collected on April 6th, 1905, gave the following figures on analysis :—

	Per cent.
Moisture (at about 110° C.)	22·51
Matter volatile on heating	33·98
Non-volatile matter	43·51
	100·0

* These oxides will contain the phosphoric acid and possibly a very little of the lime.

† The lime was precipitated only once ; it will contain traces of magnesia.

§ ‖ The figures for phosphoric acid and for total nitrogen are in each case the mean of two closely agreeing estimations.

Analysis of Non-Volatile Matter.

	Per cent.
Grit, etc. (*i.e.*, matter insoluble in hydrochloric acid, after ignition)	10·75
Oxides of iron and alumina*	13·42
Lime†	12·09
Magnesia	—
Potash (soluble in hydrochloric acid)	approx. 0·10
Phosphoric acid ($P_2 O_5$)	1·11‡
Equivalent to tribasic phosphate of lime	2·42
Yield of Nitrogen (total)	1·30‖
Nitrogen evolved on boiling the sludge for 2 hours with dilute (0·5 per cent.) potash solution on May 22nd [1]	0·06

([1] Grey mould on surface, at this date, which was avoided in sampling).

Bacteriological Analysis.

Glasgow, "Globe Fertiliser." Average of twenty samples.

B. Coli Test.—Negative result with 1 gramme.

Neutral Red Broth Test.—As regards fluorescence, positive result with 1–1,000; negative with 1–10,000 of a gramme. Growth in 1–100,000; no growth in 1–1,000,000 of a gramme.

B. Enteritidis Sporogenes Test.—Positive result with 1–100; negative with 1–1,000 of a gramme.

A larger portion of the sludge is converted into pressed cake, without being artificially dried.

The following table shows the production and sale of Globe Fertiliser and pressed cake at the Glasgow (Dalmarnock) works during the five years ending March, 1907 :—

Aggregate Quantities of 5 Years' Working.

Total amount of wet sludge dealt with. (Tons).	Total amount of pressed cake produced. (Tons).	Total amount of pressed cake sold to farmers. (Tons).	Total amount of Globe Fertiliser produced. (Tons).	Total amount of Globe Fertiliser sold to Customers. (Tons).
1,104,297 (Moisture 91% approx.).	177,566 (Moisture 60 to 65%).	124,883	5,702	5,703

Mr. Melvin gives the costs relating to these figures (excluding interest and sinking fund), as follows :—

Cost of pressing alone, per ton of pressed cake.—2s. $0\frac{5}{10}$d.

Cost of production of Globe Fertiliser, approximately.—5s. 6d. per ton, excluding pressing of wet sludge.

Total cost of production of Globe Fertiliser, approximately.—10s. per ton.

The average price obtained for the pressed cake was 8d. to 1s. per ton in bulk; the average price for the Globe Fertiliser 8s. to 10s. per ton in bulk, or 14s. per ton in bags. The purchaser pays the carriage in all cases.

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* These oxides will contain the phosphoric acid and possibly a very little of the lime.

† The lime was precipitated only once; it will contain traces of magnesia.

‡ ‖ The figures for phosphoric acid and for total nitrogen are in each case the mean of two closely agreeing estimations.

The analyses of the pressed cake and Globe Fertiliser are given by Mr. Melvin as follows :—

	Pressed Cake. Per Cent.	Globe Fertiliser. Per Cent.
(1) Organic Matter	13·84	35·20
(2) Mineral Matter	18·16	46·20
Moisture	68·00	18·60
	100·0	100·0
(1) Containing Nitrogen	·52	1·34
Equal to Ammonia	·64	1·63
Or Sulphate of Ammonia	2·49	6·33
(2) Containing Phosphoric Acid	·54	1·39
Equal to Tribasic Phosphate of Lime	1·19	3·03
Analysis Value	6s. 11d. per ton.	17s. 8d. per ton.

It will be seen, therefore, that at Dalmarnock, by careful organisation and advertising, practically the whole of the sludge is disposed of by sale, either as pressed cake or as Globe Fertiliser, the cost of the sewage treatment being in this way materially reduced. The saving effected is about 4s. per 1,000,000 gallons. During the three years ending March 31st, 1907, the whole of the pressed cake was sold to farmers. The demand is still increasing and the connection is now good enough to obviate the necessity for advertising.

Mr. Melvin states that it is more convenient to sell sludge as pressed cake than as Globe Fertiliser, partly because less work is entailed in the former case, and partly because in the manufacture of the Fertiliser much dust is produced, and he finds it difficult to get his men to wear respirators. For this reason, the Globe Fertiliser is now made during spring and autumn only, and the quantity is diminishing year by year.

In comparing the sale of pressed cake at the Dalmarnock works with sales and possibilities of sales elsewhere, it has to be specially noted that there is a branch line of railway into the Dalmarnock works, and therefore no carting is required.

Disposal of Sludge by Depositing at Sea.

226. There can be little doubt that, for cities on or near the sea-board, the disposal of sludge by taking it to sea is, in the majority of cases, the cheapest process.

Except, however, in the case of the Barrow Deep, where the London sludge is discharged, little attention appears to have been paid to the effect of the sludge upon the character of the water in the neighbourhood of the dumping area. In order to avoid nuisance and possible danger to health from the pollution of shell-fish, periodical examination of the local conditions is generally desirable wherever this method of disposal is adopted.

London.

18, 502 *et. seq.* (Fourth Report, Vol II.)

227. The plan adopted for the disposal of the London sludge was fully explained to us by Mr. M. Fitzmaurice, C.M.G., when giving evidence on July 14th, 1903.

It will be seen from the evidence that the sludge is deposited at the Barrow Deep, over a length of from five to ten miles.

The Barrow Deep is practically the open sea, being situated about 20 miles below Southend.

The following table, which has been more recently supplied to us by Mr. Fitzmaurice, shows the quantity of wet sludge, etc., deposited in the Barrow Deep during the years 1903, 1904, 1905 and 1906 :—

County of London.

Year.	Average daily quantity of sewage dealt with. (Gallons.)	Total quantity of sludge produced at Barking and Crosness. (Tons.)	Average percentage of moisture in the sludge.	Total quantity of sludge sent to sea (Tons.)	Number of trips made by the steamers.	Total cost of sending to sea, per ton of wet sludge; interest, sinking fund, steamer dues, cost of filling ships and all charges included.†
1903	259,769,466	2,563,000*	92·02%	2,563,000*	2,563	4·51d.
1904	250,590,204	2,530,000	92·28%	2,530,000	2,530	4·77d.
1905	250,698,649	2,578,000	92·16%	2,578,000	2,578	4·40d.
1906	252,882,247	2,465,000	91·95%	2,465,000	2,465	4·53d.

The average cost of sending the London sludge to sea during the years 1903 to 1906 inclusive, including interest, sinking fund, cost of filling ships, labour, fuel, repairs and all charges, was thus 4·55d. per ton of sludge containing on the average 92·1 per cent. of moisture.

228. At our request Mr. Fitzmaurice carried out some float experiments in the Barrow Deep during spring and neap tides in September, 1903. These experiments showed that, with the exception of a slight set towards the Maplin Sands at flood tide, both the ebb and the flow took a course directly along the Barrow Deep. We note, however, that floats started at the most westerly point at which the steamers begin to discharge sludge were carried back on the flood tide nearly as far as the Nore Lightship. The experiments are shown graphically in the Fourth Report of the Commission, Vol. II., p. 106.

With regard to the condition of the water in the Barrow Deep, we may refer to the evidence of Professor F. Clowes, D.Sc., F.I.C. As the result of the examination of four series of samples collected in the Barrow Deep, Dr. Clowes makes the following *Statement of Conclusions* :— Clowes, 18,636.

> " A study of these tables shows that there are on an average over 100,000,000 " of bacteria per cubic centimetre in the sludge discharged by the Council's steamers " in the Barrow Deep, and that about half this number are probably of intestinal " origin, since they are capable of growing at blood heat (37° C.); but that " immediately after the discharge of the sludge the number in the water of the " Barrow Deep is less than 2,500 per cubic centimetre, and that the number of " intestinal bacteria is generally less than 10 per cubic centimetre; indicating a " reduction of about 99·9 per cent. in the total number of bacteria and of intestinal " bacteria. Further, that the number of bacteria in the water which is carried out " of the Barrow Deep towards the mouth of the Thames, by an incoming flood tide, " is still further reduced to an average of 440 per cubic centimetre, and that the " number of intestinal bacteria has also further decreased."

The results of two experiments by Dr. Clowes upon the effect of sea water on bacterial life appear, so far as they go, to indicate that sea water does not exercise any marked inhibitory effect upon the life of the bacteria. On this showing, therefore, the above decrease in the number of bacteria in the Barrow Deep must evidently be looked upon as due to mere dilution of the sludge with sea water.

* The quantity of sludge produced per annum may be slightly different from the quantity sent to sea per annum, as a certain amount of sludge is sometimes in store at the end of one year but not sent to sea until the beginning of the following year. This difference is not shown in the above table.

† The cost of filling the ships with sludge cannot be stated separately.

Examination of the Sands in the Barrow Deep and the Thames Estuary.

Clowes 18,636. 229. In August, 1899, Dr. Clowes made a chemical and microscopical examination of samples from the sea bottom in the part of the estuary where the sludge is deposited, and in parts of it which might be affected by the sludge. His conclusions are given as follows :—

> "The results of these examinations of the sands and of the deposits in the "Barrow Deep and in other channels in the estuary of the River Thames, during "the period 2nd to 12th August, 1899, show that no sludge is carried by the tide "beyond the limits of the Barrow Deep and the Oaze Deep in a westerly or "up-river direction. The sludge which is carried in an easterly or seaward "direction must meet with so great a volume of sea water that it is quickly broken "up into innocuous bodies, and thus prevented from travelling beyond the Barrow "Deep. Accordingly no evidence of pollution by sludge was obtained in an "easterly, northerly, or southerly direction."

The subject of sea water in relation to bacteriological life is more complicated than would appear at first sight, and before conclusions can be drawn with confidence as to the effects of deposition of sludge, observations extending over a lengthened period and under a variety of conditions would, we think, be required.

Taken in conjunction with Mr. Fitzmaurice's float experiments, the above results furnish grounds for the presumption that the polluted water is for the most part carried out to the open sea on the ebb tide ; but conclusively to prove that none of it returns with the flood, extensive experiments covering the whole area of the Thames estuary would be necessary.

Glasgow.

230. There are at present (1907) two outfall works at Glasgow—the Eastern or Dalmarnock outfall and the Western or Dalmuir outfall. As has previously been said, the whole of the sludge at Dalmarnock is pressed and disposed of to farmers, either as pressed cake or as Globe Fertiliser. At Dalmuir, with the exception of the grit from the catch pit and the screenings of the sewage, both of which are mostly disposed of by sale to farmers at a price of about 8d. to 1s. per ton., plus railway carriage, the whole of the sludge is taken by the s.s. "Dalmuir," and discharged in about 80 fathoms of water some three miles below Garroch Head, a distance of about forty miles from Glasgow.

The following figures, which have been supplied to us by Mr. Thomas Melvin, relate to the disposal of sludge at Dalmuir for the three years subsequent to the opening of the works in May, 1904 :—

Aggregate Quantities for the 3 Years Ending March 31st, 1907.

Total quantity of sludge produced by precipitation. (Tons).	Average percentage of moisture.	Total quantity deposited at sea. (Tons).	Average number of journeys made per annum by the s.s. "Dalmuir."	Average cost of sending sludge to sea, including all charges except interest and sinking fund and cost of filling ships, per ton of wet sludge.	Average cost, per ton of wet sludge, of handling the sludge after it leaves the precipitation tanks, *i.e.*, the cost of filling the ship.*
915,689	86·81%	915,689	268	$2\frac{5}{10}$ d. full.	$0\frac{9}{10}$ d. full.

The cost of sending the sludge to sea during the year 1906–7, including the cost of filling the ships and the interest and sinking fund for the same period, was $5\frac{4}{10}$d. per ton, for 349,492 tons of sludge containing 85·54 per cent. of moisture. This includes interest and sinking fund on a specially constructed dock, as well as upon the steamer. The loan for the dock and the steamer is repayable, however, in equal instalments extending over the long period of sixty years. If it were repayable in thirty years, the above cost would be approximately $6\frac{2}{10}$d. per ton.

*This includes the cost of fuel for the electrically driven pumps which lift the sludge into the overhead reservoir tank.

Through the courtesy of the Glasgow City Corporation one of our officers was enabled to witness the discharge of sludge into the sea on November 20th, 1907. When the steamer reached a position about 3 miles S.S.W. of Garroch Head, between the Island of Arran and the mainland, the engines were stopped, and while the steamer continued to move slowly, she was turned so as to describe a half-circle of about $\frac{1}{4}$ of a mile in diameter. All the sludge valves were open during this time (about five minutes), the whole of the sludge being thus discharged. From the bridge of the steamer the sludge could be seen just below the surface of the clear water as a thick brown cloud. It rose to the surface behind the steamer, appearing from a distance as a band of smooth water some 20 or 30 yards wide. Many thousands of gulls which had followed the steamer immediately settled upon this. On turning and passing through the sludge band, after about eight minutes had elapsed since the steamer first began to discharge, it was seen that the band had widened considerably; and after 15 to 20 minutes, during which another turn was made, the sludge was still easily visible, though more disseminated. Probably it disappears entirely in the space of half-an-hour. The impression produced on the observer was that, even with the small tide of two knots an hour, everything but the very heavy solids would be spread over a very large area before reaching the bottom. The depth of the water was about 76 fathoms. We were informed that the tides run straight up and down the Firth, part of the incoming tide flowing between Bute and Little Cumbrae and part turning to the left towards Kilbrennan Sound. No analyses of the water in the neighbourhood of the dumping area have been made by the Local Authorities. We were told that the water in the neighbourhood of the dumping area is a favourite fishing ground.

Manchester.

231. The sludge produced at the Manchester sewage works (Davyhulme) is taken by steamer through the Manchester Ship Canal and deposited in deep water outside the North-west lightship. The lightship is situated in the open sea some 12 miles north of Rhyl and about 25 miles north-west of Liverpool.

The following figures, relating to the disposal of the Manchester sludge during the past five years, have been supplied to us by the Rivers Department of the City of Manchester.

Year ending March 31st.	Nature of sludge.	Total quantity of wet sludge produced. (Tons).	Total quantity of wet sludge sent to sea. (Tons).	Average percentage of moisture in the sludge.	Number of trips made by the steamer.	Total Sea Cost :—			
						Excluding interest and sinking fund charges, and also cost of filling ship.		Including interest and sinking fund charges (onsteamer), but excluding cost of filling ship.‡	
						Per annum.	Per ton of wet sludge.	Per annum.	Per ton of wet sludge.
1903	Chemical precipitation (mainly) and septic tank sludge	223,100	223,100	—	181	£5,283	5·7d.	£7,273	7·8d.
1904	Chemical precipitation and septic tank sludge	157,100	157,100	*85·0	129	£4,366	6·6d.	£6,356	9·7d.
†1905	Sedimentation and septic tank sludge	148,100	143,800	*85·4	123	£3,994	6·7d.	£5,984	10·0d.
†1906	Do.	155,800	142,200	86·1	136	£4,976	8·4d.	£6,966	11·8d.
†1907	Do.	181,600	176,300	86·7	163	£4,758	6·5d.	£6,748	9·2d.
	Total for 5 years -		842,500			Average	6·7d.	Average	9·5d.

* Percentage of water in septic tank sludge only.

† During these years the sludge steamer also ran on behalf of the Salford Corporation, making the following additional number of journeys :—1905, 44 ; 1906, 36 ; 1907, 25.

‡ Cost of filling ship, including sludge tank attendant, ejector attendant, repairs to ejector, and also including steam production, engines, and interest and sinking fund charges :—
Average—£123 per annum = 0·14d. per ton of wet sludge.

Salford.

232. The sludge from the Salford Corporation Sewage Works at Weaste is also sent through the Manchester Ship Canal and deposited outside the North-west lightship. The following figures, which have been supplied to us by Mr. J. Corbett, the Borough Surveyor, relate to the disposal of the Salford sludge for the years 1902–6 inclusive :—

Year.	Total quantity of sewage dealt with. (Gallons).	Total quantity of sludge produced and sent to sea. (Tons).	Average percentage of moisture in the sludge.	Number of journeys made by steamer.	Total cost, per ton of wet sludge, of sending to sea, including interest and sinking fund, canal dues, cost of filling ship and all other charges.
1902	3,802,182,451	129,000	80·2	215	
1903	3,989,619,000	135,000	78·6	225	
1904	3,335,080,548	134,900	79·5	199	
1905	3,782,877,000	134,900	75·4	184	
1906	4,227,950,000	145,400	81·0	191	
			Average for the five years		9·46d. per ton.

Note.—The percentage of water in the Salford sludge was exceptionally low during the years in question, owing partly to the fact that some old air-dried sludge which had accumulated on the works was mixed with the fresh sludge from the tanks. This had, of course, the effect of reducing the cost of sea disposal per ton.

Dublin.

233. At Dublin the whole of the sludge produced by the precipitation of the sewage with lime is taken to sea in the "s.s. Shamrock" and deposited in about 90 feet of water, some 2 miles N.E.E. of the Bailey Light on Howth. The following figures, which have been supplied to us by Mr. Spencer Harty, show the cost of disposal :—

The figures refer to the year ending October 22nd, 1907.

Total quantity of sewage treated during the year. (Gallons).	Average daily quantity of sewage dealt with. (Gallons).	Total quantity of sludge produced. (Tons).	Percentage of water in sludge.	Total quantity of sludge sent to sea. (Tons).	Number of trips made by steamer.	Cost of sending sludge to sea, including all charges,* except the cost of filling the ship and interest and sinking fund on steamer. (Per ton of sludge.)	Cost of filling ship from sludge reservoir. (Per ton of sludge.)	Total cost of sending sludge to sea, including cost of filling ship, interest and sinking fund on steamer† and all other charges.* (Per ton of sludge.)
4,829,000,000	13,230,000	114,560	90 % (approx).	114,560	320	3·47d.‡	0·049d.	5·02d.

* In the case of Dublin no harbour dues are payable; the Corporation are the owners of Pigeon House Harbour.

† The average interest and sinking fund on the cost of the steamer (£11,139) is given as follows :—

Average sinking fund	£146
Average dividend	£362
Total	£508

The loan for the steamer is included in the loan for the entire main drainage works, and is repayable in 39 years.

‡ In this figure is included an item of £196 6s. 0d. for ropes, ironmongery, uniforms, lamps, clock, bedding, etc. The vessel is a new one, and this was her first equipment. The figure 3·47d. is somewhat high on this account.

Southampton.

234. At Southampton the sludge from the sedimentation tanks is pumped into a barge which is then towed by way of Spithead to a position 3 miles from land, when the sludge is discharged. The operation is carried out by contract, the Corporation paying 1s. 2d. per cube yard of sludge. The contractor supplies the barge and the tug. The capacity of the barge is 114 cube yards. The following figures relating to Southampton have been supplied by Mr. J. A. Crowther:—

The figures refer to the year ending March, 1907.

Total quantity of sludge sent to sea.	Percentage of moisture in the sludge.	Number of journeys made by tug with barge.	Cost of disposal, excluding cost of filling barge and interest and sinking fund on pumping machinery.
16,896 cube yards or about 13,950 tons.*	about 90.	149	1s. 2d.† per cube yard or about 1s. 4·9d.* per ton.

* These are calculated figures; they are only approximate.
† This is the contract price.

235. SUMMARY OF FIGURES RELATING TO COST OF SEA DISPOSAL.

A. Place.	B. Year or years to which the figures refer.	C. Average annual quantity of sludge deposited at sea. (Tons).	D. Average percentage of water in sludge actually deposited.	E. Total cost of sea disposal, including cost of filling ship, interest and sinking fund, steamer dues and all other charges. (Per ton of sludge actually deposited.)	F. Total cost of sea disposal, including cost of filling ship, interest and sinking fund, steamer dues and all other charges. (Per ton of *dry solid matter*.)	G. Total cost of sea disposal, including cost of filling ship, interest and sinking fund, steamer dues and all charges; calculated as per ton of sludge containing 90 per cent. of water.	H. Remarks.
Glasgow -	1906-7.	305,000	86·8	5·40d.	40·9d.	*4·1d.	Large quantity of thick sludge. Loan repayable in 60 years.
Salford -	1902, 3, 4, 5, and 6.	136,000	79·0	9·45d.	45·0d.	*4·5d.	Heavy canal dues. Very thick sludge.
Dublin -	1906-7.	114,560	90·0 ap.	5·02d.	50·2d.	*5·0d.	No harbour dues and short distance to dumping area.
London -	1903, 4, 5, and 6.	2,534,000	92·0	4·55d.	56·9d.	*5·6d.	Very large quantity, but thin sludge.
Manchester-	1903, 4, 5, and 7.	168,500	86·0 ap.	9·64d.	68·9d.	*6·9d.	Heavy canal dues.
Southampton	1906-7.	13,950	90·0 ap.	16·9d.	169·0d.	16·9d.	By contract.

* These are figures obtained by calculation, on the assumption—which is probably not quite correct—that it is as easy to deal with dense as with liquid sludge. There would probably be more wear and tear of machinery in the case of dense sludge, but on the other hand the same amount of solid matter in the form of liquid sludge might mean more steamer capacity. The figures in column G. must therefore be taken as giving only an approximate idea of comparative costs.

Pressing of Sludge.

236. The plan of pressing sludge is adopted at a large number of places. Strictly speaking, it is not a method of disposing of the sludge finally; but at by far the greater number of places where pressing is done, it has the effect of converting the sludge into a form in which it can either be sold to farmers for a return of something like 6d. per ton, or can be tipped or buried without serious expense. For this reason it may generally be considered an effective means of disposing of sludge.

Very briefly, the plan is as follows:—The sludge produced by the settlement of the sewage, with or without the addition of chemicals, is first run, or pushed by hand labour, from the settling tanks into a sludge well or tank. In this well it is allowed to settle for some little time, and, after the supernatant liquor has been drawn off, the thick sludge is mixed with from 0·5 to 1 per cent. of lime (or even more) in the form of milk of lime and then forced by means of compressed air into filter presses. In this way, on the average, something like 30 or 35 per cent. of the water in the wet sludge (which may be taken at approximately 90 per cent. on the average) is removed, leaving a moist but solid cake which may contain from 50 to 65 per cent. of water. The liquid pressed from the sludge is run back into the settling tanks for re-treatment. It is strongly alkaline, owing to the lime which has been added to the wet sludge. The pressed cake is scraped from the press-cloths into trucks and either sold to farmers, buried, or tipped. The cost of the process, excluding interest and sinking fund in respect of the pressing plant, may be put at from 2s. to 5s. per ton of pressed cake produced. As will be seen from the appended table, however, it varies largely at different places, depending mainly upon:—

(*a*) The amount of lime added to the sludge;
(*b*) The kind of sludge pressed;
(*c*) The size of the works at which the plan is adopted.

The variation in cost, dependent upon the kind of sludge to be pressed and the amount of lime to be added, is readily seen from the table.

As regards the variation in cost, dependent upon the kind of sludge to be pressed, it may be pointed out that the solid matter in septic tank sludge, especially in sludge from a tank which has been in use for a long time (say, a year) without cleaning, is generally in a very fine state of division. For this reason, a large quantity of lime has usually to be added to it, in order to prevent the press-cloths becoming clogged. At Hanley, it is true, only a very small amount of lime is used, but the septic tanks are cleaned out at short intervals (once every month), and there is a considerable quantity of "clay slip" in the sewage, which apparently helps the settlement and possibly delays the putrefaction of the sludge in the septic tanks. It is to be noted also that the milk of lime is added hot at that place.

At Nelson and at Burnley, where septic tank sludge is pressed, the quantities of lime added are respectively 9·6 per cent. and 15 per cent. of the pressed cake, and the cost of pressing, excluding interest and sinking fund, is 4s. 6·9d. and 4s. 3·4d., respectively. At Rochdale it was found necessary to add at least twice as much lime to the septic tank sludge as was required for the pressing of the chemical precipitation sludge, viz., 10 per cent. as against 5 per cent., calculated on the pressed cake. At York, so much lime had to be added to the septic tank sludge, in comparison with the amount required for the treatment of sludge from precipitation tanks, that the process was abandoned as being prohibitively costly.

22,630. We may refer also to the evidence given by Dr. James B. Wilkinson, who said that at Oldham they had found great difficulty in pressing the sludge from septic tanks.

In some cases, unusually large quantities of lime are added to precipitation sludge before pressing, but this is where manufacturing waste of a greasy nature finds its way into the sewers, or where, as in the case of Ealing, a specially hard cake is made, in order

COST OF PRESSING SLUDGE.

In all cases, unless otherwise stated, the cost of pressing is taken as beginning when the sludge is out of the sedimentation tanks and is ready to be pumped into the presses. The cost of sludging the sedimentation tanks is not included. The cost of pressing is taken as ending when the pressed cake is in the trucks below the presses.

A	B	C	D	E	F	G	H	I	J	K	L
Place.	Year to which the figures refer.	Population.	Kind of sludge pressed.	Proportion of lime added to the sludge for the purpose of pressing; stated as per cent. of :—		Cost of pressing the sludge, including labour, fuel, lime, press-cloths, repairs and renewals, but excluding interest and sinking fund on pressing plant.		Cost of pressing the sludge, including labour, fuel, lime, press-cloths, repairs and renewals, *and also* interest and sinking fund on pressing plant.		How the pressed cake is disposed of.	Remarks and Notes.
				(a) The wet sludge.	(b) The pressed cake.	(a) Per ton of wet sludge.	(b) Per ton of pressed cake.	(a) Per ton of wet sludge.	(b) Per ton of pressed cake.		
Hanley	1907	66,000	Septic tank and detritus tank sludge	0·35%	1·43%	4·75d.	1s.7d.	5·75d.	1s. 11d.	Tipped at the works.	At Hanley the milk of lime is added hot to the sludge, as the latter is pumped into the sludge well. The mixture is then allowed to stand for several days before pressing. The septic tanks are cleaned out once a month.
Glasgow (Dalmarnock)	1906–7	300,000	Chemical precipitation sludge.	0·416%	2·50%	3·9d.	1s. 11·6d.	4·66d.	2s. 4d.	The pressed cake is sold to farmers at 8d. to 1s. per ton in bulk. The farmer pays carriage.	
Leyton	1906–7	120,000	Chemical precipitation sludge.	0·75%	3·75%	4·80d.	2s.	—	—	For some time past the greater part of the pressed cake has been burnt in a refuse destructor, the remainder being given away to farmers. This year (1907) the Authorities are entering into a short agreement with a contractor to load up the cake into trucks on the railway adjoining the works, the contractor to pay 6d. per ton for the cake in the trucks.	
Stockport	1906–7	91,500	Chemical precipitation sludge.	0·85%	3·25%	6·26d.	2s. 0·02d.	7·91d.	2s. 6·31d.	Given away to farmers.	
Wolverhampton	1906–7	101,000	Chemical precipitation sludge.	0·49%	2·10%	5·63d.	2s. 0·28d.	6·48d.	2s. 3·94d.	Partly by tipping (56 per cent.) and partly by barging to farmers. In the latter method of disposal the cake is conveyed in the Corporation barges to the farmers, at a nominal charge of £1 per boat load. This does not always cover the cost of conveyance and upkeep of boats, etc. The average loss is 1s. 2d. per boat-load of 2 tons, or 0·73d. per ton of cake.	
Bolton	1906	170,000	Chemical precipitation sludge.	1·12%	5·6%	5·4d.	2s. 2·9d.	10·2d.	4s. 2·9d.	Removed by farmers, the Corporation paying 3d. per ton of pressed cake.	
Bury	1906–7	50,000	Chemical precipitation sludge.	0·67%	3·62%	5·2d.	2s. 4d.	—	—	Given away to farmers free of charge. Assistance is given in loading.	The figures of cost for Bury include the cost of sludging the precipitation tanks. This addition to the cost is very small, however, as it involves the labour of only one man.
Richmond (Surrey)	1907	62,885	Chemical precipitation sludge with some septic tank sludge.	1·0% ap.	5·0% ap.	5·6d.	2s. 4d.	7.2d.	3s.	The pressed cake is tipped into barges and taken away by a contractor who supplies the barges. It is sold by him to farmers in Essex and Kent. The cost to the Richmond Main Sewerage Board in 1907 was 1s. 9d. per ton of pressed cake or 4·25d. per ton of wet sludge.	With regard to the capital expenditure, it should be noted that the engine plant and machinery is in duplicate. The plant is only worked one shift of 10 hours per day; if it were worked in two shifts, the cost of pressing, including interest and sinking fund, would be 6·4d. per ton of wet sludge, or 2s. 8d. per ton of pressed cake.
Hyde	1903	32,000	Chemical precipitation sludge.	1·25%	3·75%	10d.	2s. 6d.	1s. 3·3d.	3s. 10d.	Removed by farmers, free of cost, with the exception of a surplus quantity, for which 9d. per ton was paid to clear it away.	The figures of cost for Hyde include the cost of tank sludging. This is a small item, however, and only raises the cost very slightly.
Great Harwood	1906–7	22,500	Chemical precipitation sludge.		3·0%	—	2s. 6·2d.	—	3s. 7·2d.	Sold to farmers at 6d. per ton.	
Chorley	1906–7	26,500	Chemical precipitation sludge.	0·42%	4·25%	3·21d.	2s. 8·2d.	—	—	By sale to farmers: tons cwts. 1s. 6d. per 1-horse load = about 1 10 1s. 9d. per 2-horse load = about 2 0	
Wimbledon	1906–7	52,500	Chemical precipitation sludge.	1·0%	5·0%	7·25d.	3s. 1d.	8·75d.	3s. 7·75d.	By burying and burning.	
Royton	1906–7	12,500	Chemical precipitation sludge.		4·14%	—	3s. 2d.	—	4s. 1d.	Given away to farmers, who remove it themselves.	The figures of cost for Royton include the cost of sludging the tanks. This item is small, however, and against it must be put the fact that the steam required for the pressing is raised by Destructor fire. The cost of coal is included in the figures, but coal is only used to assist in raising the steam.
Leigh and Atherton	1906–7	63,600	Chemical precipitation sludge.	—	4·3%	—	3s. 4·98d.	—	4s. 1·58d.	Part deposited on portions of sewage farm not used for sewage treatment, and part sold to farmers at a present price of 1s. per 1-horse load and 1s. 6d. per 2-horse load. This is about 6d. per ton on the average.	The figure for cost of pressing, including interest and sinking fund, is estimated.
Middleton	1906–7	25,600	Settling tank sludge	0·67%	4·6%	6·5d.	3s. 7d.	7·5d.	4s. 1d.	Given away to farmers.	
Willesden	1905, 6 and 7	66,000	Chemical precipitation sludge.	2·2%	13·35%	8d.	3s. 9.2d.	8·58d.	4s. 0·78d.	Mostly by tipping on the sewage farm. During the early part of the present year (1907), however, a portion of the pressed cake has been disposed of to farmers, who have paid the cost of the railway freight only, the Council paying the cost of the carriage to the railway station.	The large percentage of lime used in the pressing of sludge at Willesden is due to the fact that the sewage there contains much laundry waste, and is of a rather greasy character.
Burnley	1905–6	80,000	Septic and detritus tank sludge.	3·4%	15·5%	12·85d.	4s. 3·45d	1s 1·96d.	4s. 7.91d.	Sold at the sewage works to farmers for 10d. per ton.	
Colchester	1906–7	41,000	Chemical precipitation sludge.	2·8%	11·2%	12·75d.	4s. 3·5d.	1s. 3·25d.	5s. 1d.	The pressed cake is disposed of to farmers at a price of 1s. per cart-load.	
Ealing (Southern Works)	1906–7	40,000	Chemical precipitation and settling tank sludge.	5·0%	20·0%	10·4d.	4s. 4d.	11·70d.	4s. 10·5d.	The cake is dropped into trucks and conveyed by hydraulic lift to refuse destructors, where it is burnt.	The sludge is pressed specially well at Ealing, on account of the subsequent burning.
Maidenhead	1906–7	14,000	Chemical precipitation sludge.	—	4·2%	—	4s. 4·1d.	—	—	All the pressed cake and also a fair proportion of air-dried sludge is sold to farmers and market gardeners at 6d. per cart-load.	
Nelson	1906–7	37,000	Septic and settling tank sludge.	—	9·6%	—	4s. 6·9d.	—	6s. 0·4d.	Given away to farmers.	The labour cost in connection with the sludge pressing is estimated.
A	B	C	D	E	F	G	H	I	J	K	L

To face page 168.

that it may subsequently be burnt. Generally speaking, there is no difficulty in pressing the sludge from precipitation or sedimentation tanks. It may be pointed out that the sludge from simple sedimentation requires, as a rule, the addition of more lime than the sludge derived from sedimentation after precipitation with chemicals; this is indicated in the table.

It may be useful to add here that success in pressing, whatever kind of sludge is being dealt with, depends very largely upon the intimate mixture of the milk of lime and the sludge. The dissolved lime has the effect of agglomerating the solids of the sludge, while the fine particles of undissolved lime, becoming interposed between the sludge particles, apparently provide small channels for the escape of the water. We may also mention that at York, Mr. Graham, the manager of the Sewage Works, found it useful to allow a small quantity of milk of lime to pass into the presses before the sludge, as the thin coating of solid lime thus formed on the press-cloths facilitated the subsequent pressing of the sludge and the removal of the cake.

Nuisance from Smell.

237. Speaking generally, properly pressed sludge when in the form of a solid cake does not give rise to serious nuisance from smell, and if exposed to the air in dry weather, it soon becomes entirely inoffensive. It has, however, a slight smell of fresh sewage, and if kept moist, *e.g.*, if it is exposed to the air during wet weather, it soon becomes putrid and gives rise to offensive odours. For this reason it should, if possible, be stored under cover, until it can be spread over land or dug into trenches or buried. At York, where a large quantity of pressed cake was tipped in the open, considerable nuisance is said to have arisen until Mr. Creer, the city engineer, adopted the plan of burying it, 5 or 6 feet thick, under a thin layer of soil and turf, when the nuisance entirely ceased. Incidentally, an uneven field is being levelled in this way.

Since there is almost always serious nuisance inside the press house, it is necessary that the house should be properly ventilated. It should also be situated as far as possible from any habitation, if complaint of nuisance is to be avoided.

Disposal of the Pressed Cake.

238. Pressed sludge can usually be disposed of to neighbouring farmers at about 6d. per ton. This, however, depends to a considerable extent upon the district in which the sewage works are situated. In some cases, *e.g.*, at Bury, Ealing (Northern Works), Wolverhampton, and Richmond, where the works are situated in densely populated districts, or are far removed from a railway, or in the case of a large town where the amount of sludge is greater than the neighbouring farmers require, the pressed cake has to be given away, or a small fee has to be paid for its removal.

The form of the pressed cake also affects its saleability; *e.g.*, at Burnley, where the Corporation break up the pressed cake immediately after pressing, a ready market is now obtained.

Composition of Pressed Cake.

239. The following figures of analysis give the chief mineral constituents and the nitrogen in the pressed cake from Chorley (Lancashire) and Dorking (Surrey), after complete drying at 110° C. These may be taken as more or less typical for domestic sewage, but there is more than the average quantity of lime in the Dorking pressed cake. The Chorley sludge is produced by the addition of about 9 grains per gallon of alumino-ferric to a sewage which is almost entirely domestic in character and of about average strength. The Chorley drainage area is sewered on the combined system. The Dorking sludge is obtained by the addition of about 5 grains per gallon of lime to a sewage of rather over average strength, and which, except for a small quantity of

brewery waste, is also almost entirely domestic in character. Dorking is sewered on the partially separate system.

	Chorley pressed cake after drying at 110° C. Sample drawn in April, 1905.	Dorking pressed cake after drying at 110° C. Sample drawn in April, 1905.
Grit, etc. (*i.e.*, matter insoluble in hydrochloric acid, after ignition)	25·30	6·84
Oxides of iron and alumina *	9·37	3·46
Lime †	10·32	23·16
Phosphoric acid (P_2O_5) ‡	0·98	0·66
Equivalent to tribasic phosphate of lime	2·14	1·44
Nitrogen (total) ‡	1·28	0·89
Nitrogen evolved on boiling the sludge for two hours with dilute (0·5 per cent.) potash solution	0·13 (May 21st.)	0·03 (May 20th.)

At Chorley the cake is sold for about 10d. to 1s. per ton, but at Dorking it is given away.

The calculated value of those two sludges in the form of pressed cake (50 per cent. moisture), as judged by their manurial constituents alone, is about 6s. to 7s. per ton, but, as experience shows, the market value is less.

Cost of Pressing Sludge.

240. In the majority of the cases cited in the table it has been impossible to ascertain the actual percentage of water in the wet sludge dealt with and in the pressed cake produced. We think, however, that it may be taken broadly that wet sludge contains on the average from 90 to 95 per cent. of water, and pressed cake about 55 per cent. of water. Upon this basis, and dividing our examples into two groups, we estimate the cost of pressing sludge as follows :—

Group I.

In this group we include towns having a population of about 30,000 and upwards, where the preliminary treatment consists either in chemical precipitation followed by sedimentation or in simple sedimentation, and where the sewage does not contain manufacturing waste of a kind likely to necessitate the addition of an unusual quantity of lime to the sludge before pressing.

If the sludge derived from precipitation or sedimentation tanks in these circumstances were to be pressed, it would require the addition of about 2 to 4 per cent. of lime, calculated on the pressed cake produced ; and the cost of pressing, including lime, fuel, labour, press cloths, renewals and repairs, but excluding interest and sinking fund, would amount to from 2s. to 2s. 6d. per ton of pressed cake (55 per cent. water). This would be equivalent to from 5·3d. to 6·6d. per ton of wet sludge, containing 90 per cent. of water.

The interest and sinking fund charges, as given in the table, vary from 4½d. to 1s. 1d. per ton of pressed cake produced, or an average of 9d. per ton of pressed cake. This would be equivalent to 2d. per ton of wet sludge containing 90 per cent. of water. On this basis the *total* cost of pressing, including lime, fuel, labour, press-cloths, renewals and repairs, and also interest and sinking fund, would amount to from 2s. 9d. to 3s. 3d. per ton of pressed cake produced (55 per cent. water), or from 7·3d. to 8·66d. per ton of wet sludge, containing 90 per cent. of water.

Assuming that the pressed cake could be disposed of to farmers without further cost at a price of 6d. per ton, the total cost of sludge disposal at such places would be approximately from 6d. to 7·3d. per ton of wet sludge, including interest and sinking fund charges.

* These oxides will contain the phosphoric acid and possibly a very little of the lime.
† The lime was only precipitated once ; it will contain traces of magnesia.
‡ The figures for phosphoric acid and for total nitrogen are the mean of two closely agreeing estimations.

Group II.

In this group we include towns having a population under 30,000 and also places where 5 to 20 per cent. of lime (calculated on the pressed cake) has to be added to the sludge before pressing, either because the sewage contains much grease, or because septic tank sludge has to be dealt with.

At such places the cost of pressing, including lime, fuel, labour, press-cloths, renewals and repairs, but excluding interest and sinking fund, would probably vary from 3s. to 5s. per ton of pressed cake (55 per cent. water), or from 8d. to 1s. 1½d. per ton of wet sludge containing 90 per cent. of water.

The cost of pressing, including lime, fuel, labour, press-cloths, renewals and repairs, and also interest and sinking fund, at such places would be from 3s. 9d. to 5s. 9d. per ton of pressed cake (55 per cent. water), or from 10d. to 1s. 3½d. per ton of wet sludge containing 90 per cent. of water.

Assuming that the pressed cake could be disposed of without further cost at a price of about 6d. per ton, the net cost of sludge disposal at these places would be from 8·66d. to 1s. 2d. per ton of wet sludge, including loan charges.

From these figures it will be seen that, in the case of large towns, the cost of the disposal of sludge by pressing is about the same as the cost of depositing it at sea. For small towns or for places where septic tank sludge has to be disposed of, the cost is considerably greater. In all cases the cost turns very much upon whether there is a ready sale for the pressed cake, and this is dependent upon having facilities for carting or sending by rail to outlying districts. The pressed cake is worth much more than 6d. per ton, judged by its manurial constituents ; the reason that it fetches such a low price is the relatively high cost of carriage upon a mixture containing of necessity a large proportion of water, grit, and carbonaceous matter.

Shallow Burial of Sludge in the Ground.

241. This plan of sludge disposal consists in mixing the wet sludge from precipitation, settlement, or septic tanks as rapidly and as thoroughly as possible with surface soil. It is usually carried out in the following manner : Small V-shaped trenches, about 2 feet wide at the top and (excluding banking above the surface of the soil) about 1 foot deep, of sufficient capacity to hold the quantity of wet sludge to be disposed of, are cut, if possible, a month or even two months before they are likely to be required, in order to dry and disintegrate the soil. The wet sludge is then run into the trenches and immediately covered over by shovelling in the earth of the banks. The area thus treated is allowed to remain untouched until it is fairly dry, after which it is ploughed and either set aside for cropping or used again for more sludge.

This plan is not widely followed at present, excepting at sewage farms, but it has lately been worked with considerable success by Mr. J. D. Watson, at Birmingham, Mr. C. G. Mason, at Guildford, and Dr. G. J. Fowler, at Withington, in conjunction with artificial filters. By this plan the sludge is cheaply and effectively disposed of, but in wet weather the trenches, both empty and full, require a long time to dry, and, where an offensive sludge has to be dealt with, local nuisance from smell may easily arise.

At Birmingham, where the septic tank sludge has very little smell, little or no nuisance arises, notwithstanding the enormous quantities dealt with ; but at Guildford, owing to the presence of brewery waste in the sewage, there is considerable smell from the trenches. We may point out, however, that strongly smelling sludge can be to a large extent deodorised by the addition of a moderate quantity of lime, and for this reason, though we have no practical experience of the plan, we think that at those places where an offensive sludge had to be dealt with, serious nuisance could be avoided without great cost. At small or medium-sized works, where septic tanks are in use and are cleaned out, say, once every six months, it appears to us that it would be quite practicable to add sufficient lime to the sludge to deodorise it, *before conducting it to the trenches.* This method of disposal would be peculiarly suitable for the treatment of the sludge which is removed from septic tanks at fairly long intervals of time, for in that case a period of dry weather could be selected for the trenching operations.

Area of Land Required.

242. With regard to the kind of land and the area required for the annual disposal of 1,000 tons of wet sludge (90 to 95 per cent. of water), we may quote some particulars which have been given to us.

Mr. J. D. Watson writes (April, 1907) :—

"I cannot differentiate between one kind of land and another, since we have in "the valley of the Tame a great variety of soil. . . . Even in one field we have "occasionally considerable areas of very close marl and equally great areas of "fairly porous gravelly marl. The figure which I give, therefore, is one which "embraces various kinds of soil, but as it is the result of an average taken over "three years, I think it may be assumed to be fairly accurate as representing "*medium quality* of land."

The following table shows the amount of wet sludge dealt with at Birmingham and the area of land used in the form of trenches :—

Year.	Tons of wet sludge dealt with by trenching.	Area of trenches in square yards.	Area of trenches in square yards per 1,000 tons of wet sludge.
1903–4	208,350	265,870	1,276
1904–5	239,203	248,132	1,038
1905–6	109,255	74,167	680
1906–7	104,780	82,747	788

"Climatic conditions have also a considerable bearing upon this question. "In dry weather more sludge can be got rid of on the same area of land than "in wet weather. Methods of working have also a good deal to do with the "results obtained. For instance, where possible it is advisable to cut the trenches "a month or two in advance of their being required, in order to dry the land as "thoroughly as possible. . . .

"Speaking generally, I should say that a quarter of an acre of medium quality "land, worked under usual conditions in this country, is amply sufficient to deal "with 1,000 tons of wet sludge (90 per cent. to 95 per cent. water) per annum."

Mr. C. G. Mason writes (April, 1907) :—

"During 1906, 18,720 tons of liquid sludge were applied to nine acres of "land at Guildford. In the winter months one acre is sufficient to deal with "approximately 2,000 tons, and in the summer months nearly twice that "quantity can be dealt with on the same area of land. The land available for "sludge purposes at Guildford may be described as excellent, consisting as it does "of a light sandy loam, overlying a bed of sand to the depth of 6 feet, with "the water level from 3 to 6 feet below the surface, according to season."

Mr. Mason says that he has not had any experience in dealing with liquid sludge upon unsuitable land, but from general experience he estimates the areas required annually for the disposal of 1,000 tons of wet sludge to be as follows :—

Good land - - - - - - - - - - - - - - ½ acre.
Medium land - - - - - - - - - - - - - 1 „
Bad land - - - - - - - - - - - - - - 2 acres.

"The plan of trenching has certainly been very successful at Guildford, and has "saved the Corporation a large sum yearly from its inception, but I should not care "to make an experiment with wet stiff clay land, an absorbent sub-soil being to "my way of thinking an essential necessity for trenching the precipitated matter "from sewage tanks."

As regards the Withington Sewage Works of the Manchester City Corporation, where the same plan of sludge disposal has been adopted, Dr. G. J. Fowler writes (January, 1908) as follows :—

"The soil at Withington may be described as a sandy loam with a water-logged "subsoil. I should certainly class it as 'medium' soil. For the annual disposal "of 1,000 tons of wet sludge I am of opinion that two acres of such soil should "be provided, though the more soil you have at your disposal the better. Some-

"thing will here depend upon the character of the sludge. The Withington sludge "itself contains a good proportion of sand (77 per cent. SiO_2; 1·76 per cent. "Al_2O_3); a sludge containing a larger percentage of clay, *e.g.*, Davyhulme sludge "(44·3 per cent. SiO_2; 20·85 per cent. Al_2O_3), might require a greater area of "such land.

"Even with the best sandy soil I should recommend, if possible, one acre per "1,000 tons of wet sludge, if it is to be dealt with to the best advantage.

"I am very doubtful whether it is possible to dispose of sludge on clay land, "without some provision of shallow lagoons artificially drained, *e.g.*, by banks of "clinker at frequent intervals.

"Some addition of lime is advisable in all cases where this has not been added "in the course of chemical treatment, either to neutralise the acid produced by "the decomposition of fats or the sulphuric acid produced by the oxidation of "sulphides in sludge from septic tanks."

Allowing ample margin for contingencies, cropping and bad weather, we should from these figures recommend the provision of the following areas of land for the yearly disposal of 1,000 tons of wet sludge (90 to 95 per cent. water):—

Good or fairly good soil	1 acre.
Medium soil	2 acres.
Stiff clay soil,—at least	3 „

Care would have to be taken, as Mr. Watson suggests, to prepare the trenches beforehand, so that the soil might be as dry as possible, and also to remove the sludge from septic tanks in the dry season of the year.

It would be important, moreover, in calculating the amount of sludge likely to be produced at a given place, to include storm water sludge, especially if * stand-by tanks were used for the treatment of the storm water. Tanks of this kind would have to be frequently sludged, and consequently special areas of trenches would be required.

At those places where continuous filters of coarse material were adopted, it would also be necessary to provide for the disposal of the sludge settled out from the effluent.

It must not be forgotten that the disposal of sludge upon land is temporarily interfered with by snow and frost.

Cost.

243. As regards the cost of sludge disposal by burial in the ground, the following particulars relating to Birmingham, Guildford, and Withington have been supplied to us. In all three cases the cost is taken as beginning after the sludge has left the sedimentation tank (*i.e.*, the actual sludging of a tank is not included), and as ending when the trenches are filled in with earth.

BIRMINGHAM.

TOTAL COST OF CONVEYING SLUDGE TO THE LAND AND DEPOSITING IT IN TRENCHES CUT FOR THE PURPOSE.

	Year 1905.	Year 1906.	First 11 months of 1907.
Working expenses of steam plant and attendance:	£. s. d.	£. s. d.	£ s. d.
Engineers and Stokers	65 16 2	70 4 6	76 3 9
Oil, waste, valves, etc.	100 0 0	106 0 0	92 0 0
Coal	83 16 3	89 8 9	77 12 6
Digging trenches, covering sludge, filling in trenches, etc.	719 18 2	644 6 9	516 9 0
Total working cost	969 10 7	910 0 0	762 5 3
Interest on Capital Outlay at 5 per cent., viz., Pump House, Sludge Main, etc.	220 0 0	213 0 0	130 0 0
Rent of land	23 0 0	22 0 0	13 0 0
Total cost, including interest on capital	£1,212 10 7	£1,145 0 0	£905 5 3
Total amount of wet sludge dealt with (90 per cent. to 95 per cent. water)	Tons. 84,890	Tons. 61,996	Tons. 48,872

* *See* section dealing with treatment of Storm Water Sewage, page 204.

At Birmingham the total cost of this method of sludge disposal, including labour, pumping, fuel, interest and sinking fund and rent of land, was therefore approximately **4·0**d. per ton of wet sludge containing from 90 to 95 per cent. of water.

Guildford.

Total cost of conveying the sludge to the land and depositing it in trenches cut for the purpose. The figures refer to the year 1905–6.

	£	s.	d.
Two men employed continuously for regulating and covering in the sludge	101	8	0
One man 3 days per week attending to steam boiler and sludge pump	31	4	0
Firewood for boiler (4 loads @ £1)	4	0	0
Disinfectants	20	0	0
30 tons of fuel for generating steam for pumping sludge	36	0	0
Renewals and sundries	2	8	0
Annual working cost	195	0	0
Add interest and sinking fund for 17 acres of land	252	15	3
	447	15	3

The total quantity of liquid sludge dealt with during the year was 18,720 tons. The cost at Guildford was thus **5·2***d.* per ton of wet sludge, containing from 90 to 95 per cent. of water.

Withington.

The following statement relative to the cost of trenching at Withington has been given to us by Dr. Fowler (January, 1908):—

"The cost of excavating a measured trench, capable of holding 1 cubic yard of "sludge, has been found by the manager of the Withington Works, Mr. C. H. Ball, "to be 1·3d. This low cost is due to the fact that the soil thrown up on either side "of the excavation practically doubles the holding capacity.

"Taking the average cost for the whole year per ton of wet sludge for cutting "and filling trenches, it comes to 2·4d. and the total cost for sludge disposal works "out at about 5·5d. This is exclusive of the rent of land, which would bring the "total up to about **7·0**d., if only so much land is charged for as is absolutely "necessary."

The population draining to the Withington Works is approximately 59,000. The total annual production of wet sludge is something like 14,000 tons.

Lagooning or Air Drying.

244. A lagoon in connection with sludge disposal may be described as an earth tank, from 1 to 6 feet deep, constructed by excavation and banking, or banking alone, with a bottom layer composed of clinker or some such material, in which are laid one or two drains. Occasionally the whole enclosure is constructed of clinker, the banking being made with an easy slope, formed naturally by the fall of the clinker.

Lagooning consists simply in filling such a tank with wet sludge, by gravitation or by pumping, and allowing it to remain there until, partly by evaporation and partly by draining, the sludge becomes dry enough to be removed by spade. When the sludge reaches this state, it is usually wheeled out of the lagoon and dumped on waste land.

There is in our opinion very little to be said for the lagooning of sludge. Once in the lagoon the sludge may take from 2 to 6 months to dry, according to the weather, and during the greater part of this time smell may be said to arise from it. Further, when the sludge is dry enough to be removed, it has still to be disposed of, and being usually moist and closely bound together, it is not readily taken by farmers. The time required by the sludge to dry, however, depends to a great extent upon the depth and the draining of the lagoon. At Darwen, where a large quantity of lime is added to the sludge, and where this mixture is given further settlement in special tanks, the lagoons are only filled to a depth of about 1 foot. As the result of this whole procedure, the

sludge is usually just spadeable in 2 or 3 days—a very short space of time. It is then given away to farmers, the Corporation filling the carts free of charge. At Accrington the lagooned sludge, when dry enough to be spadeable (this takes from 2 to 3 months in dry weather, while in wet weather it may require about 6 months), is sent up the steep side of the quarry in which the works are situated, by means of a truckway, and deposited in canal barges, to be taken to the more purely agricultural districts of West Lancashire. The barge owners pay, on the average, about £2 10s. per barge load of 45 tons. The barges are loaded by the Joint Sewerage Board, the average cost of filling a boat from the works being about 25s.

At Leeds lagooned sludge has gradually accumulated during the past ten years, only a few thousand tons per annum having been disposed of to farmers. We are, however, informed by Mr. G. A. Hart that, as the result of practical advertisement, arrangements have now been made for reducing those accumulations, the sludge being sent by rail or canal to the agricultural districts around Leeds. The loading costs the Corporation 1s. 2d. per ton of sludge (60 per cent. moisture), the farmers who receive it paying the carriage, which amounts to about 1s. 6d. per ton. During the past 7 months 6,000 tons have been disposed of in this way.

It is possible to lessen very greatly the smell from a sludge lagoon by covering the surface of the sludge with soil. This can only be done, however, after the sludge has been in the lagoon sufficiently long to allow of its surface drying into a cake. The plan, moreover, is one which might result in serious danger to workmen or children, especially if the lagoons were deep.

Covering Land with Sludge.

245. This plan consists in simply flooding an area of flat land, which has previously been ploughed, with wet sludge to a depth of 3 or 4 inches. In a few days the liquid portion of the sludge drains away, leaving a layer of sludge which cracks and curls up as it dries. The only examples of the method that we are acquainted with are at Birmingham and Bolton. At Birmingham Mr. J. D. Watson has carried out the plan with success. In his evidence he stated :—

> " If the sludge has been subjected to digestion in septic tanks for a sufficiently " long period, it loses its characteristic pungent and offensive odour. It may either " be pumped into trenches or even put on the surface of land and exposed to the " air until dry, without giving rise to smell ; when thus treated it rapidly settles " down in bulk, and as it dries the surface cracks up. In the course of a few " months it assumes the appearance of a rich black soil."

Watson, 25,034

At Bolton a somewhat similar plan is adopted for the disposal of part of the precipitation sludge from the Hacken sewage works. In this case the land is first ploughed and the sludge is allowed to spread over it, the flow being equalised as much as possible by means of cross grips cut through the furrows. Another plan which is adopted, when possible, is to drill the soil (as for mangolds) and then run the sludge along the bottom of the drills. When the sludge is dry, it is covered over by ploughing or splitting the drills and a crop is taken.

The land treated in this way at Bolton is either sandy clay loam or sandy gravel.

Mr. Ashton, the Manager of the Bolton works, estimates the area of land required for the annual disposal of 1,000 tons of sludge containing 90 per cent. of water as follows :—

(1) Good, or fairly good soil - - - - - - - $\frac{3}{4}$ of an acre.
(2) Medium soil such as sandy loam - - - - - 1 acre.
(3) Heavy soil - - - - - - - - - - 2 acres.

The plan would be quite unsuited for strongly smelling sludge, unless the land used for the purpose were far removed from houses or public roads, or unless the sludge were deodorised in the first instance by the addition of lime or some other suitable substance.

Sludges which give rise to little or no smell are very exceptional. The Birmingham septic tank sludge is comparatively free from smell, but the majority of septic tank sludges from domestic sewage, even when they have remained for a long period of time in the tank, are very far from odourless. We have made no observations at Bolton, but the sewage there contains much manufacturing waste, which may possibly keep down smell.

Cost.

Birmingham.

246. Two sets of figures have been given to us by Mr. Watson, viz., the cost of disposing of the sludge from the Saltley septic tanks, and the cost of disposing of the sludge from the Dortmund or silt tanks at Minworth, these latter being used for the further settlement of the septic tank liquor before filtration. In the first case the sludge is pumped, but in the second no pumping is necessary. In both cases it is septic tank sludge that is dealt with.

Total Cost of Conveying the Septic Tank Sludge from Saltley to the Land and Depositing it.

Working expenses of steam plant and attendance.	Year 1905.	Year 1906.	First 11 Months of 1907.
	£ s. d.	£ s. d.	£ s. d.
Engineers and Stokers	33 13 9	26 10 10	48 11 8
Oil, waste, valves, etc.	44 0 0	34 13 4	58 13 4
Coal	37 2 6	29 5 0	49 10 0
Distribution of sludge over land	45 13 3	50 7 4	42 12 1
Total working cost	160 9 6	140 16 6	199 7 1
Interest at 5% on Capital outlay—viz., Pump House, Sludge Main, etc.	130 0 0	137 0 0	191 0 0
Rent of land	13 0 0	16 0 0	19 0 0
Total cost, including Interest on Capital	£303 9 6	£293 16 6	£409 7 1
Total amount of wet sludge dealt with (90% to 95% water)	50,365 tons	42,278 tons	71,265 tons

The cost of this method of disposal was thus **1·47**d. per ton of wet sludge, containing from 90 to 95 per cent. of water.

Total Cost of Conveying Septic Sludge from Minworth and Depositing it on the Land.

	Year 1905.	Year 1906.	First 11 months of 1907.
	£ s. d.	£ s. d.	£ s. d.
Attendance to Silt Tanks	6 10 0	14 5 3	18 2 1
Distribution and digging into land	16 15 0	37 14 9	44 1 5
Total working cost	23 5 0	52 0 0	62 3 6
Interest on Capital Outlay, viz., Silt Main	57 10 0	57 10 0	57 10 0
Rent of Land	9 0 0	20 0 0	13 5 10
Total cost, including Interest on Capital	£89 15 0	£129 10 0	£132 19 4
Total amount of wet sludge dealt with (90% water)	6,226 tons.	21,605 tons.	36,299 tons.

The cost of disposal in this case was therefore **1·32**d. per ton of wet sludge containing 90 per cent.* of water.

Bolton.

247. In the case of Bolton the total cost of the plan for the year ending November 30th, 1907, when 25,000 tons of sludge containing 90 per cent. of water were dealt with on 25 acres, was approximately 5·04d. per ton.

* The above figure of 90 per cent. water in the sludge was in this case actually determined.

It should be noted, however, that the sludge gravitates to the land from the precipitation works at Hacken—a distance of some miles—through a conduit which is used chiefly for the conveyance of tank liquor to the land for filtration. No portion of the interest and sinking fund charges on this conduit are included in the above cost for sludge disposal.

Burning of Sludge.

248. There have been many attempts to dispose of sewage sludge by burning it either alone or mixed with house refuse, coal, oil, or resin. Most of these have failed, owing either to the heavy cost of drying the sludge before burning, or to the fact that the attempt was made on wet sludge containing something like 90 per cent. of water. It is practicable, however, to burn pressed cake. At Ealing (Southern Works) Mr. Charles Jones has for some years disposed of pressed sludge (containing about 60 per cent. of water) in this way. At those works the pressed cake is dropped from the presses into trucks, which are then conveyed by a hydraulic lift to the destructor furnaces. There it is mixed with dry house refuse, in the proportion of about 1½ or 2 parts of dry refuse to 1 of pressed cake, and burnt. The steam generated is utilised for lime mixing, for sludge-pressing and the manufacture of artificial paving slabs, and for pumping a portion of the sewage. We have not been able to ascertain the cost of the process, but about 2,500 to 3,000 tons of pressed cake have been disposed of per annum in this way during the years 1905, 1906, and 1907.

249. Reference may also be made to the evidence given by Mr. K. F. Campbell of Huddersfield in regard to an *experimental* plant. At that place a portion of the sludge obtained by means of chemical precipitation is pressed and, having been tipped into feeding bins at the back of the furnaces, is there mixed with 20 per cent. of coke breeze and fed by hand into the furnaces. The burning plant consists of a two-cell Horsfall destructor, each cell having a grate area of 30 square feet, with a drying hearth at the back; the cells are placed side by side and each is fitted with a patent Silent Steam Blower. The furnaces are so arranged that all the fumes given off by the pressed cake, in drying, have to pass over the hottest part of the fire before they escape to the chimney. Campbell, 21,787–802.

Mr. Campbell's original intention was to burn the pressed sludge mixed with an equal quantity of town refuse, but owing to the difficulty in getting the refuse to the sewage works, this was abandoned and coke breeze was substituted. Occasionally a little engine slack has been used, mixed with the coke breeze, but this is not a regular occurrence. During the year 1907 a trial has been made with gas-works clinker containing a fair proportion of coke and combustible matter. The following particulars relating to the years 1901–6, inclusive, have been kindly given to us by Mr. Campbell:—

Year ending:—	Sludge Cake burnt in destructors.		Coke Breeze used.		Coal used.		Gasworks clinker used.	
	TONS.	CWT.	TONS.	CWT.	TONS.	CWT.	TONS	CWT.
March, 1901	5,421	14	911	1	121	0	101	16
,, 1902	34	8	7	10	—		—	
,, 1903	136	0	27	9	—		—	
,, 1904	220	14	42	11	—		—	
,, 1905	61	3	7	8	2	17	—	
,, 1906	74	9	12	9	—		—	
Total	5,948	8	1,008	8	123	17	101	16

The proportion of fuel added to the pressed cake was thus about 1 to 5.

The clinker obtained from the burnt sludge is rather too friable for use in sewage filters, but Mr. Campbell states that when it is ground up and mixed with cement or lime it forms an excellent mortar, of which much has been used in the present re-construction of the works.

Cost.

The cost of pressing and burning varies with the price of the materials (lime, coke breeze, etc.). The following are the average costs for each :—

PRESSING.

Cost per ton of Pressed Cake Produced.

	s.	d.
Labour	1	5·3
Lime (13s. 3d. per ton)	–	9·3
Press Cloths	–	3·7
Total	2s.	6·3d.

BURNING.

Cost per ton of Sludge Cake Burnt.

	s.	d.
Coke Breeze (7s. 6d. per ton)	1	6·4
Stokers	–	7·2
Mixers	–	5·3
Total	2s.	6·9d.
Total cost of pressing and burning (per ton)	5s.	1·2d.

These figures do not include cost of power for pressing, on the one hand, but, on the other, no allowance has been made for fuel value or for clinker produced.

It will be seen that the above process, as carried out on a large experimental scale at Huddersfield, is costly, but probably the whole of the final product can be utilised and the sludge is entirely got rid of.

Extraction of Valuable Substances from Sewage Sludge.

250. The chief example of the extraction of a valuable substance from sewage sludge is afforded by Bradford. As is well known, the sewage there contains a considerable quantity of wool-scouring liquor and is consequently of a very greasy nature. For some years experiments having for their object the extraction of the grease have been in progress, and Mr. J. Garfield, the City Engineer, has now been so far successful that the return from the sale of the products more than meets the working expenses of the tank treatment of the sewage,* leaving out of account the charges in respect of principal and interest on loans. The dry weather flow of sewage is approximately 13,000,000 gallons per day, about half being trade waste. Of the trade waste 20 per cent. is wool-scouring liquor, and of this about 90 per cent. is treated by manufacturers for the recovery of grease before being discharged from the premises. The remaining 80 per cent. of trade waste comes from dyers, printers, chemical manufacturers, tar distillers, cloth manufacturers, waste pullers and scourers, yarn finishers, cloth washers, carbonizers, silk manufacturers, tanners, oil distillers, paper manufacturers, size manufacturers, brewers and galvanizers. In all, about 274 traders discharge their waste liquor into the sewers.

The process of treating the sewage at the works is as follows : The sewage is passed through detritus tanks, from which about 10 cubic yards of detritus are removed per day. It is then screened and sulphuric acid is added in such quantity that there is an excess equal to 10 parts of acid (H_2SO_4) per 100 000. The acid sewage is subsequently

* The treatment of the sewage at Bradford does not go beyond precipitation.

passed through settling tanks, used in series, the tank liquor being discharged into the Bradford Beck in a slightly acid condition. The following figures give the average chemical composition of the sewage and the tank liquor :—

	Parts per 100,000.	
	Crude sewage.	Tank liquor.
Suspended matter	84·0	16·0
Solids in solution	181·0	224·0
"Oxygen absorbed" in 4 hours	17·90	11·18
Free ammonia	3·00	1·87
Albuminoid ammonia	2·45	1·80

The sludge is removed from the settling tank into cast iron vats, where a further quantity of sulphuric acid is added and the temperature of the sludge is raised by means of exhaust steam from the boilers to about 100°C. It is then run into steel rams and forced by means of compressed air into the filter presses. The filter presses are heated by steam, and the process of pressing is continued from 12 to 24 hours, hot sludge and steam being alternately admitted to the press. The pressed liquor, which consists of water and fat, is run into special vessels for the separation of the fat, after which the fat is boiled with acid and black oxide of manganese, in order to bring it into a marketable condition.

The amount of wet sludge produced in a year is about 100,000 tons. It contains about 80·15 per cent. of water and 7·43 per cent. of grease, which is equivalent to 37·7 per cent. of grease on the dry solid matter.

The amount of pressed cake produced during the year is about 20,000 tons. This contains about 27 per cent. of water. Part of the pressed cake is used for fuel and is burnt in specially constructed brick furnaces; the fuel value is about 1s. 6d. per ton. Part is sold to farmers at 3s. 6d. per ton on rail at the works. Another portion is disintegrated and sold as manure at 5s. 6d. per ton, whilst 6s. 3d. per ton is obtained for the driest portion of the disintegrated pressed cake.

For the six months ending September 30th, 1907, the total expenditure on the sewage works, exclusive of principal and interest on loans, amounted to £9,960 0s. 3d. and the receipts from the sale of grease, etc., to £11,726 15s.

The following table, which has been given to us by Mr. Garfield, shows the figures in detail. The expenditure includes the salaries of the chemical and clerical staff, and the whole of the costs in connection with the Sewage Disposal Works, except the Chief Engineer's salary, and interest and sinking fund on loans.

Expenditure.	£	s.	d.	Receipts.	£	s.	d.
To Sulphuric Acid, Fuel and Stores	7,250	3	4	By Grease, Manure, etc.	11,726	15	–
To Salaries and Wages	1,907	12	–½				
To Gas	161	11	3				
To Water	90	19	10				
To Insurance and Sundries	122	13	9½				
To Rent, Rates and Taxes	427	–	–				
To Balance	1,766	14	9				
£.	11,726	15	–	£.	11,726	15	–

251. We may also refer to a process of sludge distillation (Watson and Butterfield's Patent Sludge Distilling Process), which was brought to our notice by Mr. George Watson of

the Horsfall Destructor Co., Ltd. The object of this process, an experimental installation of which was inspected by one of our officers on July 6th, 1907, is to recover the nitrogen from the sludge in the form of ammonia, and to utilise at the same time the carbonaceous matter for the purpose of generating heat. The following description of the process has been supplied by Mr. George Watson. It must, of course, be understood that we are not responsible for the claims advanced by Mr. Watson, in regard to the process. We can express no opinion in regard to them.

" The treatment of the sludge as taken from the precipitation tanks involves, on this principle, three " separate processes. Firstly, the removal of a portion of the water by mechanical means; secondly, " the removal of a further portion of the water by drying; and thirdly, the destructive distillation of the " partially dried sludge."

(1) *Pressing.*

" The sludge when taken from the precipitation tanks contains about 90 per cent. of water. The " best method at present in use for getting rid of some of this water is filter-pressing. By this means the " proportion of water in the sludge may be reduced to 50 or 60 per cent.'

" Sludge containing 90 per cent. of water, when pressed until it contains 60 per cent., is reduced to " one-fourth of its original bulk; if pressed until it contains 50 per cent. of water, it is reduced to one- " fifth of its original bulk. The cost of filter-pressing is in one instance as low as 1s. 10d. per ton of " pressed cake, but the average cost at the present time may be put at from 2s. 3d. to 2s. 6d. per ton " of pressed cake containing from 50 to 60 per cent. of water."

(2) *Drying.*

" After the sludge has been filter-pressed, it is necessary to dry it until it contains only 20 to 25 per " cent. of water, before putting it into the retort for distillation. Wherever a sufficiently large space " of ground is available and only a comparatively small quantity of sludge has to be treated, the drying " may be most economically effected by exposing sheds. Where considerations of capital are not deterrent " or where space is limited, the sludge may be dried by passing it through mechanically driven rotary " cylindrical driers, heated by the hot waste gases of combustion, which leave the flues round the distilling " retort after having heated the retort.

" The sludge as it leaves the filter-presses can be readily transported to the driers on band-conveyors. " Filter-pressed sludge containing, say, 60 per cent. of water, when dried until it contains 20 per cent. " of water, is reduced approximately to half its weight and bulk.

" The sludge is now in the form of sufficiently dried cakes to be easily transportable mechanically " by conveyors or elevators to the retort, and suitable for the treatment by destructive distillation at a " high temperature.

" The gases from the interior of the cylindrical drier, before reaching the chimney, may be passed " through a scrubber which recovers any ammonia given off by the sludge during drying operations, " thus effectually preventing any smell which may arise from this source.

" The cost of drying is estimated at 1s. 6d. per ton of dried sludge (containing 20 per cent. of water), " which is equivalent to a cost of 9d. per ton of filter-pressed sludge containing 60 per cent. of water."

(3) *Destructive Distillation.*

" The retort used for the distillation may be of firebrick, but is preferably made of cast iron, and is " oval in section, so as to enable the heat to penetrate readily through the material in the interior.

" The retort is set vertically and is slightly larger in section at the bottom than at the top, so as to " facilitate the downward movement of the sludge cake. The top of the retort is closed air-tight by a " cup and cone arrangement, through which the dried sludge cake is fed at regular intervals. The bottom " of the retort is similarly closed by a cone, which can be operated so as to let out the spent residue from " the distillation, as may be desired. The retort is placed in a brickwork setting and is heated by the " combustion of gas in a combustion chamber and in flues passing around and up its sides, preferably " in a spiral path.

" The volatile products arising from the distillation are taken off towards the top of the retort through " a pipe connected to the side, and the gases are pulled forward and outward by an exhauster which " maintains a pressure inside the retort slightly below the atmospheric pressure.

" After leaving the retort the volatile products of distillation are passed through a condenser and " subsequently through a scrubber, which extracts the moisture, oil, tar and ammonia. The inflammable " gas which now remains is passed into the combustion chamber of the retort and there burnt.

" The heat obtained from the combustion of this gas is sufficient to maintain the retort at the desired " temperature, but an auxiliary source of heat is provided by a gas producer or furnace which is used in " starting the operation.

" The lower part of the retort is maintained at a temperature of 1,500° to 1,800° F.

" Steam is blown into the retort, near the bottom, and in passing through the hot zone in the retort " it reacts on the carbonaceous material of the sludge, and in the presence of the lime, and at the high tem- " perature there existing, the nitrogen in the sludge is liberated and evolved as ammonia.

" The products obtained from the distillation are: (1) Oil; (2) ammonia; (3) combustible gas; " and (4) mineral residue."

(1) *Oil.*

" The oil is run off from the top of the ammoniacal liquor coming from the condenser, by means of an " oil separating tank. The oil thus obtained has not yet been thoroughly examined, but it probably has " a value far higher than that of fuel oil, although this is not necessary for the economical success of the " process.

" The yield of oil depends on the method of distillation, being much greater if a comparatively cool " zone is maintained at the top of the retort. The yield of oil from the sewage of different localities also " varies greatly."

(2) *Ammonia.*

" The ammoniacal liquor from the condenser and scrubbers is treated with sulphuric acid in the ordinary " way and is converted into ammonium sulphate.

" The yield of ammonia varies to some extent with the locality from which the sewage is derived. The " economical disposal of sewage sludge in this way depends on the recovery of the ammonia from the " sludge in sufficient quantity to cover the cost of treatment."

(3) *Gas.*

" The gas is burnt around the retort and provides the heat necessary for the distillation."

(4) *Residue.*

" The spent residue from the retort is freed entirely from any trace of organic matter by its treat- " ment in the retort, and is of a light friable nature and easily reduced to a fine powder. It contains " lime and some phosphates and is in a form very suitable for direct application to land, either alone " or enriched by the addition of concentrated manures. On the other hand it might possibly be used " as a precipitant for the sewage, along with a small proportion of fresh lime. By constantly using the " same material over again, the percentage of phosphate of lime in the material would be so increased " as to make it valuable as a manure. Where too much iron is not present, the residue can be used as " a cement of fair quality.

" The quantity of residue remaining after distillation is about 50 per cent. of the solid material present " in the sludge, or 40 per cent. of the sludge (containing 20 per cent. of water) as charged into the retort. " The percentage of residue varies in different localities according to the amount of surface water run " into the sewers. In some cases a large amount of mineral matter is thus swept into the sewage, which " increases the proportion of inorganic solids in the sludge."

The following figures show the amounts of the different products obtained by this process of distillation. In every case, to avoid confusion, the figures given are calculated per ton of *absolutely dry sludge*—that is, per ton of solid matter in the sludge.

Date.	Locality from which the sludge was obtained.	Oil.	Ammonium Sulphate.	Residue.
October, 1906 -	Bradford - - -	Not measured.	97·7 lbs.	42% (small sample only tested).
„ „ -	Bury - - -	30 gallons.	120 lbs.	47% do.
„ „ -	„ - - -	37 „	124 lbs.	47% do.
„ „ -	Southall - - -	6·2 „	81·7 lbs.	47% do.
April, 1907 - -	Leeds - - -	24 „	103 lbs.	50% do.
October, 1907 -	„ - - -	*Not measured.	109·2 lbs.	50% (one ton distilled in large retort).

* The retort was too hot at the top to yield oil.

Comparison of Cost of Different Methods of Disposal of Sludge.

252. The cost of disposing of sludge depends not merely upon the method adopted, but also, and to a large extent, upon the local circumstances of each place. This must be carefully borne in mind in considering the following table :—

Comparative Cost of the Various Methods of Sludge Disposal, as instanced by the Examples Given.

Method of sludge disposal.	Number of examples.	Maximum and minimum cost of the process, in pence, per ton of sludge containing 90 per cent of water, including interest and sinking fund and all other charges.*	Average cost of process, in pence, per ton of sludge containing 90 per cent of water, including interest and sinking fund and all other charges.
Covering land with sludge - - -	3	Minimum 1·32d. Maximum 2·8d.	say, 2d.
Sea disposal - - - - - - -	6	Minimum 4·1d. Maximum 6·9d.	say, 5d.
Trenching in soil - - - - -	3	Minimum 4·0d. Maximum 7·0d.	say, 5d.
Pressing. Group I. - - - -	10	Minimum 4·8d. Maximum 7·3d *	say, 6d.
Pressing. Group II. - - - -	11	Minimum 7·7d. Maximum 12·6d.*	say, 11·5d.
Pressing and burning - - - -	1 (experimental)	13·3d. (excluding interest and sinking fund.)	say, 18d.†

The cheapest examples of disposing of sludge come under the heading of "covering land with sludge." This is, of course, what would be expected, for little labour is necessary in connection with the plan. The success of the method depends upon having a sufficient area of good, or fairly good, soil in flat formation. On account of smell, the plan would, as a rule, only be suitable where the sewage works were far removed from houses and public roads.

The two cases of an actual profit arising out of the disposal of the sludge, viz., Kingston-on-Thames and Bradford (Yorkshire) are not included in the table.

In the table no credit has been given either for the manurial value of the sludge disposed of by covering land or trenching, or for the fuel value of the sludge and the production of clinker in the "burning" method.

With regard to the burning of sludge, if this process were so modified as to permit of the recovery of the nitrogen of the sludge, its cost would probably be much reduced.

* Owing to the great variations in the actual figures for interest and sinking fund, mainly because of the different dates at which the sewage works were constructed, we have been obliged, in dealing with "Pressing," to take an approximate average figure for this item, viz. 9d. per ton of pressed cake containing 55 per cent. of water, or 2d. per ton of sludge containing 90 per cent. of water.

† This figure is an estimate.

MANURIAL VALUE OF SEWAGE SLUDGE.

253. Opinions in regard to the manurial value of sludge were of so conflicting a character that we thought it advisable to institute some accurate experiments with various sewage sludges.

Through the kindness of the Board of Agriculture and Fisheries, these experiments were carried out at several collegiate centres under their supervision.

The experiments took the form of three series as follows :—

Series 1.—Experiments with mangolds and swedes at five collegiate centres, under the supervision of Dr. W. Somerville.

Series 2.—Experiments with grass at eight collegiate centres under the direction of Professor Middleton, and at Woburn by Dr. J. A. Voelcker.

Series 3.—Pot-culture experiments at Woburn by Dr. J. A. Voelcker.

The reports on these experiments are given in Appendix VIII.

In all three series of experiments the same sewage sludges were used, and in each case the sludge was artificially dried before being sent to the experimental stations. Its carriage would otherwise have presented much difficulty.

The sludges were derived as follows :—

SLUDGE No. 1.—*Composite precipitation sludge produced by the Native Guano Co., Ltd., at Kingston-on-Thames :—*

This sludge consists of the precipitate deposited in continuous flow tanks, as the result of adding alumino-ferric, blood, charcoal and clay (together about 50 grains per gallon) to the Kingston sewage, which is mainly domestic in character, but which contains a small proportion of waste liquors from breweries and a gas works.

Having been pressed into cake and then artificially dried at a temperature of about 75° Centigrade, it was stored under cover for some time previous to sampling.

SLUDGE No. 2.—*Composite precipitation sludge from Dorking, Surrey :—*

This sludge consists of the precipitate deposited in continuous flow tanks as the result of adding lime (10 grains per gallon) and alumino-ferric (5 grains per gallon) to the Dorking sewage, which is almost entirely domestic in character.

It was first pressed into cake and then dried by placing portions of it in thin layers near a boiler. A further quantity of lime, equivalent to about 120 lbs. per ton of pressed cake, was added previous to the pressing.

SLUDGE No. 3.—*Alumino-ferric precipitation sludge from Chorley, Lancashire :—*

This sludge consists of the precipitate deposited in quiescent settling tanks as the result of the addition of alumino-ferric (9 grains per gallon) to the Chorley sewage, which is domestic in character.

Having been pressed and partially dried under cover, it was further dried by placing it in small quantities on either side of a boiler. Previous to the pressing a quantity of lime, equivalent to 1 cwt. per ton of pressed cake, was added to the sludge.

SLUDGE No. 4.—*Composite precipitation sludge from Leeds, prepared by Alton's process :—*

This sludge consists of the precipitate deposited in a continuous flow tank as the result of adding calcium phosphate (4 to 5 grains per gallon) in acid solution and subsequently lime (about 1 grain per gallon) to the Leeds sewage, which is rather dilute and contains a considerable proportion of waste liquors from various manufactories.

The wet sludge was first drained in a lagoon and afterwards dried artificially by placing it near a boiler.

Sludge No. 5.—*Septic tank sludge from Leeds :—*

This sludge consists of the deposit in an open septic tank which had been receiving Leeds sewage for a period of three years. The flow of sewage into the tank during this time was sufficient to fill it once every twenty-four hours. The wet sludge was first drained in a lagoon and afterwards dried artificially by placing it near a boiler.

Sludge No. 6.—*Settled sewage sludge from Leeds :—*

This sludge consists of the deposit settling in the second of a series of continuous flow subsidence tanks used at Leeds for the treatment of the main flow of sewage. The wet sludge was first drained in a lagoon and afterwards dried artificially by placing it near a boiler.

Sludge No. 7.—*Composite precipitation sludge from Glasgow (Dalmarnock), known as " Globe Fertilizer " :—*

This sludge consists of the precipitate deposited in continuous flow tanks as the result of the addition of persulphate of iron (8 grains per gallon) and lime (4 to 5 grains per gallon) to the Glasgow (Dalmarnock) sewage, which contains much manufacturing waste.

The sludge was first pressed and then artificially dried at a temperature of 65° to 75° Centigrade, and finally passed through a pan mill.

The chemical compositions of the sludges used in the experiments are given in the Reports, but we may say here that No. 1 sludge contained the most nitrogen and phosphoric acid, and Nos. 2 and 4 the most lime.

Series 1.

Dr. Somerville's Experiments with Turnips, Mangolds, and Swedes.

254. Table I. gives the names of the five experimental stations where this series of experiments was carried out, together with the nature of the soil and the crop grown.

Table I.

Place.	Nature of Soil.	Crop Grown.
Rothamsted Experimental Station (Mr. G. D. Hall) -	Strong flinty loam overlying chalk.	Mangolds.
Agricultural Department, Cambridge University (Prof. Middleton).	Moderate gritty loam overlying gault.	Mangolds.
Agricultural Department, Leeds University (Prof. Seton).	Strong drift soil overlying the coal measures.	Swedes.
South-Eastern Agricultural College, Wye (Prof. Dunstan).	Strong flinty loam overlying chalk.	Swedes.
Glasgow and West of Scotland College of Agriculture (Prof. Wright).	Strong loam on the carboniferous formation.	Turnips.

The scheme of the experiments was as follows :—

At each station twenty-two plots in duplicate, each $\frac{1}{20}$ of an acre, were selected.

It was decided to use, as far as possible, 40 lbs. of nitrogen and 36 lbs. of phosphoric acid per acre, and 2,072 lbs. of sludge No. 1 were required to supply these amounts. Since the other sludges contained less nitrogen and phosphoric acid than No. 1, 2,072 lbs. did not in their case supply as much as 40 lbs. nitrogen and 36 lbs. phosphoric acid. It was obviously impossible to apply equal quantities of the manurial constituents from all the sludges, while it was also inadvisable to attempt to get over this by the addition of artificial manures. On the first seven duplicate plots an amount equal to 2,072 lbs. per acre of each of the sludges was therefore used. Plots 8*a* and 8*b* received an amount equal to half the above quantity per acre of No. 1 sludge (*i.e.*, 1,036 lbs. per acre), Plots 9*a* and 9*b* received no sludge, and Plots 10*a* and 10*b* received 3,108 lbs. per acre of No. 1 sludge. The other twelve duplicate plots were used for comparative experiments with No. 1 sludge mixed with either sulphate of ammonia, superphosphate, or both, and also for experiments with sulphate of ammonia, superphosphate and fish meal, either together or alone.

The whole of the experimental area received an equal dressing of potash salt, supplying 30 lbs. of potash (K_2O) per acre :—

" The season was somewhat abnormal in character and, on the whole, not very favourable to the action " of manures. From the Midlands northwards the early part of the summer was characterised by great " deficiency of rain, with the result that seed germinated badly and young plants received a check in growth. " At Leeds the root crop on the experimental area was a total failure, so that no figures are available from " this centre.

" At the other centres the yields were fair, being above the average at Cambridge and below the average " at Glasgow."

255. From the results obtained with given weights of nitrogen and phosphoric acid added in the form of artificial manures, Dr. Somerville determines the sensitiveness of the soil to manurial treatment, showing :—

(1) That nitrogen alone (sulphate of ammonia), unsupported by phosphates, produced no positive result at any of the centres, so far as turnips and swedes are concerned. On the other hand, with mangolds at Rothamsted and Cambridge a large increase was obtained.

(2) That the use of 20 lbs. of nitrogen (sulphate of ammonia) per acre, together with phosphoric acid in the form of superphosphate, produced a marked increase of crop in every case.

(3) That 18 lbs. per acre of phosphoric aid (as superphosphate) alone produced no increase of crop, while, with the exception of Wye, 36 lbs. of phosphoric acid per acre produced an increase at all the centres.

Comparing the results obtained with sludge No. 1 alone and mixed with either superphosphate or sulphate of ammonia, he shows :—

(1) That the phosphate of the sludge is less active than the phosphate in the superphosphate, because the addition of a further quantity of phosphoric acid in the form of superphosphate produced a greater relative effect in the former case than the latter.

(2) That there are similar indications with regard to the nitrogen of the sludge.

From the direct comparison of the effects of equal weights of nitrogen (20 lbs. and 40 lbs. respectively) and phosphoric acid (18 lbs. and 36 lbs.) derived from sludge No. 1 and from sulphate of ammonia with super-phosphate and with fish meal, Dr. Somerville shows that the sludge-grown crop is in nearly every case considerably inferior in weight to the crop grown with artificial manure. In several cases the sludge-grown crop was smaller than the crop grown on the unmanured plot (No. 9).

In comparing the results obtained with all seven sludges, he says :—

" Taking the average of all the centres and the average of the seven plots that got 2,072 lb. per acre of " sludge, we find that the yield works out at 19 tons 7 cwt. per acre, which is practically a $\frac{1}{2}$ ton less than " the average yield on the unmanured plot (No. 9). Or, looked at from another point of view, it will be " seen that the highest yield of any of the sludges is that of No. 2 (Dorking) on Plot 6, where it amounts " to 20 tons $5\frac{3}{4}$ cwt., a figure that is lower than the average yield on any of the plots receiving artificial " manure."

Dr. Somerville's general conclusion is as follows :—

" So far as these experiments go, they show that in the season of 1905 none of the sludges experi- " mented with produced any consistent manurial effect on the growth of turnips, swedes, or mangolds. Al- " though the season was not a good one for the growth of the root crops, it permitted artificial manures to " exert a considerable influence upon the yield of this crop. We would, therefore, appear to be justified in " drawing the conclusion that the nitrogen and phosphoric acid of sludge are in a much less available form " than the same substances in sulphate of ammonia, superphosphate, and fish meal."

In view of the difficulty of the whole subject, it was thought desirable to continue the experiments for another year, this time with hay as the crop to be grown.

Series 2.

(a) *Experiments with Sewage Sludge upon Hay, under the Supervision of Mr. T. H. Middleton.*

256. The general scheme of this series of experiments was similar to that of Series 1, except that eight centres were chosen and the crop grown was hay.

At most of the centres twenty-five plots of $\frac{1}{20}$ of an acre each (not in duplicate) were used, but at Cambridge there were thirty-four plots.

The first seven plots received equal weights of the seven sludges; Plots 8, 9, and 11 different weights of Sludge No. 1; Plots 10 and 23 were unmanured; Plots 12, 13 and 14 received No. 1 Sludge with various artificial manures; Plots 15 to 22 combinations of artificial manures alone, while Plots 24 and 25 received lime alone. The artificial manures employed in this instance were basic slag and sulphate of ammonia.

The sludges were the same as in Series 1, but made a year later: as will be seen from the chemical analyses, their composition varies slightly. Sludge No. 1 again contained the most nitrogen and phosphoric aid, and Nos. 2 and 4 the most lime.

Table II. gives the names of the centres at which the experiments were carried out with the nature of the soil and the condition of the meadow land.

TABLE II.

Centre.	Nature of Soil.	Condition of Meadow Land.
(1) The North of Scotland College of Agriculture, Aberdeen.	Poor, wet clay.	Field had been in grass for six or seven years, but was in extremely poor condition.
(2) The West of Scotland College of Agriculture, Glasgow.	Heavy clay.	Grass in its first year.
(3) The Armstrong College, Newcastle-on-Tyne.	Clay loam.	Field had been in grass for about thirty years.
(4) The University, Leeds.	Medium loam.	Old meadow land.
(5) The University College of North Wales, Bangor.	Gravelly soil.	Old meadow land.
(6) The Agricultural Department, Cambridge University.	Medium, but sticky loam.	Pasture of fifteen to twenty years' standing.
(7) The Rothamsted Experimental Station, Harpenden, Herts.	Heavy clay loam.	Old meadow land.
(8) The South-Eastern Agricultural College, Wye, Kent.	Somewhat stiff loam overlying chalk.	Pasture of some years' standing.

257. Mr. Middleton's report should be referred to, but we may say that the broad results show that at the northern stations, where the wet summer was favourable to slow-acting manures, the application of sludge seems to have been useful.

In the South of England, where the hay is cut much earlier, the sludges produced no results whatever.

Speaking generally, the two sludges containing the most lime, viz., Nos. 2 and 4, gave the best results among the sludge grown crops.

In a general survey of these experiments and the experiments of Series 1, Mr. Middleton says:—

"The figures obtained in this experiment and in the corresponding experiments made last year are not "of a satisfactory character, and do not permit of any conclusions as to the relative money values of sludge "and artificial manures.

"The only definite conclusion which may be stated is that, for root crops and grass, the action of the "nitrogenous and phosphatic constituents of sludge is very slow, as compared with the effect produced by "nitrogen and phosphates supplied in ordinary artificial manures.

"For such crops as mangolds, potatoes and swedes, which have a short period of growth and require "quick acting manures, sewage sludges would not appear to be well adapted, and if they are employed they "should be applied in tons rather than in hundredweights per acre.

"On the other hand, although these experiments do not supply the evidence, it seems likely that sludge "used in proper quantities would form a good dressing for the slow growing plants of many permanent pastures "and meadows.

"Sludge is unlikely to give satisfaction on the very poor clay-soil pastures which are so much benefited "by basic slag, but for old grass land of moderate quality it should prove useful."

It is instructive to note the indication that sludges produced by precipitation with lime are probably more valuable as manures than sludges derived from precipitation with salts of alumina or iron. As is well known, phosphate of lime is much more readily assimilated by plants than phosphate of iron or alumina.

This series of experiments upon hay is being continued at some of the stations for another year without any fresh application of sludge.

(b) *Experiments with Sewage Sludge on Grass Land at Woburn, by Dr. J. A. Voelcker.*

258. These experiments were on much the same lines as those carried out under Mr. Middleton.

Eleven plots of $\frac{1}{10}$ of an acre were marked out in a field that had been long in grass, but which could only be described as of moderate quality. The field is on the junction of the Lower Greensand with the Oxford Clay, the soil partaking of the character of both formations.

The first seven plots were respectively dressed with each of the seven sludges in quantity sufficient to supply 40 lb. of nitrogen per acre, Plots 8, 10 and 11 received ordinary mixtures of artificial manures, and Plot 9 was left unmanured. Plots 8, 10 and 11 also received a dressing of lime. Exactly the same sludges were used as in Series 2 (*a*).

"All the sludges, with the exception of Nos. 2 and 4 (which were rather 'sticky' in nature, and would "in practice be rather difficult to sow), were in fair condition and could be easily manipulated. Very little "rain fell during the months of February and March, the recorded rainfall at Woburn being only 0·99 inch "for February and 0·83 inch for March. In April, however, there was much more, and on April 12th 0·44 "inch of rain fell, this being the first real washing which the manurial applications received. This fact "and the absence of warmth by which the season was marked no doubt militated much against the sludges "increasing any decided benefit, and it is, indeed, very probable that the results now recorded cannot fairly "be taken as a guide to the real or relative values of the sludges. In all experiments conducted on grass land "it is unfair, and often misleading, to take the results of a single year as conclusive, and especially is this the "case when an abnormal season like that of 1907 enters into the calculation."

When the hay was cut on July 15th it was found that there was little difference in weight of crop from any of the first six plots, the produce ranging from about 2 tons per acre (Plot 1) to about 2 tons 4 cwt. per acre (Plot 4). Plot 7, receiving Sludge No. 7; Plot 8, receiving superphosphate, 3 cwt. per acre and lime 5 cwt.; and Plot 9, which received no manure, gave from about 2 tons 5 cwt. (Plot 8) to about 2 tons 7 cwt. (Plot 7) of hay.

Plot 10 (superphosphate 3 cwt., lime 5 cwt., sulphate of ammonia $\frac{3}{4}$ cwt.) gave about 2 tons 8 cwt., and Plot 11 (sulphate of ammonia $1\frac{1}{2}$ cwt.), 3 tons 3 cwt.

259. Summarising these results Dr. Voelcker says :—

"There is, I think, little more to be said than that, for all practical purposes, the sludges did not 'tell' "during this season, but that they require longer time to show their influence, and that the only clear benefit "was to be traced to the more quickly acting (because more soluble) material, sulphate of ammonia. That "even this increase will, in the end, be a beneficial one, is by no means certain, for the mere 'flushing' of a "grass field to give an extra cut for hay by no means results necessarily in the improvement of the pasture "permanently. Here, again, continuation of the experiment for other years is called for."

Series 3.

Pot Culture Experiments at Woburn by Dr. J. A. Voelcker (1907).

260. In addition to the foregoing experiments with grass, Dr. Voelcker also carried out a detailed series of experiments with wheat at the Woburn Pot Culture Station, experiments which involved much care and trouble.

The same seven sludges were used.

The experiments were divided into three groups :—

(1) A comparison of the manurial effect, on the wheat crop, of one kind of sewage sludge as against another, when these were respectively applied in quantities calculated to supply 40 lbs. of nitrogen per acre.

(2) A comparison of the effect of each individual sludge with that of an artificial dressing composed of superphosphate, rape dust and lime, calculated to supply the same amounts of phosphoric acid, nitrogen and lime as did the corresponding sludge.

(3) A comparison of the cost of increase of crop obtained by the addition of sludge and by artificial manures of known cost. In this experiment the sludges were used in equal weights (2 tons per acre) and compared with dressings of artificial manures such as a farmer would be likely to use.

Every experiment was carried out in triplicate, the plan being to grow the wheat in pots of certain size filled with soil of known composition. In filling the pot the last fifth of the soil was thoroughly incorporated with the sludge or artificial manure used in the experiment. The pots held 40 and 32 lbs. of soil. Control experiments for each size of pot were also made at the same time.

When the pots were all filled, on December 5th, 1906, they were each sown with twelve seeds of wheat, the young plants being thinned out to six in each pot on April 11th, 1907. As regards the plants removed at the time Dr. Voelcker says :—

"... a comparison of the rootlets of the plants then removed showed very little difference between "one sludge and another, but in each case the artificial equivalents had given the larger and stronger root "growth."

"About April 22nd the first change in appearance showed itself, the sludge grown plants being then "slightly in advance of the untreated ('control') ones, and the flag presenting a darker colour. The plants "of Sludge 1 and 4 were the best of the series. On April 25th the top dressing of sulphate of ammonia was "applied in experiment 3.

"By May 24th further differences were noticeable; the 'equivalents' were in most cases rather stronger "than the corresponding sludges. Of the sludges, No. 2 alone seemed no better than the untreated lot, the "others generally showing improvement. Growth was rapid from now, and in each case the 'equivalents' "went to the front, and by June 20th Sludge No. 2, which up to then had been behind the others, now shot "ahead and was the best of the sludges. Sludges 4 and 6 had very irregular plants. As the ripening pro- "ceeded, the most noticeable point was that the straw was distinctly shorter in the case of the 'equivalents' "than with the sludges themselves; this held good in every case. The untreated lots ripened off first, then "the sludges, and lastly the equivalents. Photographs and measurements of the plants were taken just before "harvesting, this latter being done on August 28th, the corn being subsequently threshed out and weighed."

261. Having set out the results in tabular form and examined the results in detail, Dr. Voelcker draws the following conclusions :—

"(1) That the different sewage sludges, when used in sufficient quantity to supply 40 lbs. "of nitrogen per acre, are capable of increasing the yield of both corn and straw by 10 to 12 per "cent. above the unmanured produce.

"(2) That 'artificial equivalents' of the different sewage sludges applied as above will give "rather better results, the increase in corn and straw being 16 to 17 per cent. over the unmanured "produce."

"(3) That the tendency of the use of sewage sludges is to produce a greater length of straw."

"(4) That as between different sludges, those have done the best which contain the most "moisture and the most lime."

"(5) That the value of the sludge does not turn mainly upon the amount of nitrogenous organic "matters contained, but that these may, indeed, be in a form incapable of ready assimilation and "requiring lime for their decomposition."

"(6) That from a practical point of view none of the sewage sludges used would be worth 10s. "a ton on the farm for wheat-growing purposes."

262. Acting on the suggestions of Mr. Middleton and Dr. Voelcker, we have decided to continue these experiments for another year. The indications are that the manurial constituents of sewage sludge act much more slowly than those of ordinary artificial manures, and for this reason the second year results may be of considerable importance.

Unit for unit the nitrogen and the phosphoric acid of sludge seem to be of less value, manurially, than the nitrogen and phosphoric acid of artificial manures; at any rate so far as the first year of application is concerned. It also appears that sewage sludge is not a suitable dressing for quickly growing plants, unless it is applied in very large quantities per acre.

The important practical consideration, however, is not whether the manurial constituents of artificial manures are, unit for unit, more valuable than the manurial constituents of sewage sludge, but whether a given increase of crop can be produced more cheaply with sewage sludge than with artificial manures. Sewage sludge has undoubtedly a manurial value, but the manurial constituents being of necessity mixed with such a large proportion of grit, etc., the question of its economic use as a manure depends, to a large extent, upon the cost of carriage.

In the case of sewage sludge, likely to contain anthrax spores, it would of course be unwise to apply it to land. It would, however, be only in rare cases that such spores would be apt to be present.

SLUDGING OF MILL DAMS.

263. Our attention has been drawn to the evils attending the practice of the sludging of mill dams on rivers, and, although the matter is not directly within our terms of reference, we thought it desirable to take some evidence in regard to it, as it was alleged that the practice frequently gave rise to serious nuisance.

Many of the rivers in this country, particularly in Cheshire, Lancashire, and Yorkshire, are largely used by manufacturers for power and other purposes, and to facilitate the use of the water for such purposes, dams or reservoirs are constructed either in the bed of the stream itself, or near thereto.

In course of time, the mill dams become silted up with solid matters which are brought down in suspension by the stream, and which, owing to the velocity of the stream being reduced, settle in the mill dam. It is necessary to empty these solid matters out of the mill dams from time to time, and the evidence shows that when the accumulations are sent down the river in bulk serious pollution may take place and a nuisance may be caused. The liability to nuisance is of course greater in the case of rivers which, in their course above the mill dams, receive polluting matters such as sewage and manufacturing effluents, but it was represented to us that nuisance also occurs, though in a lesser degree, on rivers which are not so polluted.

Somerville, 20230–4, 20254–5. Tatton, 20264. Halliwell, 20477–86. Wilson, 23915, 23935–6. Tatton, 20265–73. Wilson, 23934.

The witnesses whom we examined specially in regard to these matters were :—

Mr. Herbert Hughes, C.M.G., Clerk of the Millowners' Association of the River Don.

Mr. J. Selwyn Rawson, Millowner.

Mr. A. F. Somerville, Chairman of the Sanitary Committee of the Somerset County Council.

Mr. R. A. Tatton, Chief Inspector of the Mersey and Irwell Joint Committee.

Mr. E. Halliwell, Chief Inspector of the Ribble Joint Committee.

Mr. H. Maclean Wilson, Chief Inspector of the West Riding of Yorkshire Rivers Board.

From the evidence of these witnesses, we find that there are three principal methods of removing the accumulations of solid matters, or sludge as it is termed, from dams, namely, (*a*) by opening the sluices and allowing the accumulated water to flush out the sludge ; (*b*) by turning the water of the stream through the dam and employing men to push and carry the sludge into the current of water, by which it is washed out of the dam into the stream ; and (*c*) by running the water out and wheeling the sludge to a tip outside the dam.

264. The main provisions of the general law affecting this matter are contained in the Rivers Pollution Prevention Act, 1876. There are, besides, two special Acts, namely, the Mersey and Irwell Joint Committee Act, 1892, in force in the area under the jurisdiction of the Mersey and Irwell Joint Committee ; and the West Riding of Yorkshire Rivers Act, 1894, in force in the area under the jurisdiction of the West Riding of Yorkshire Rivers Board.

By Section 2 of the Rivers Pollution Prevention Act, 1876, it is provided that "every person who puts or causes to be put or to fall, or knowingly permits to be put or to fall into any stream, so as . . . . . to interfere with its due flow, or to pollute its waters, the solid refuse of any manufactory, manufacturing process or quarry, or any rubbish or cinders, or any other waste or any putrid solid matter, shall be deemed to have committed an offence against this Act." By Section 17 the Act is not to apply to or affect the lawful exercise of any rights of impounding or diverting water ; and by Section 20, the term "solid matter" if not inconsistent with the context, does not include particles of matter in suspension in water.

The effect of these provisions upon the sludging out of mill dams has been the subject of a judgment in the Court of Appeal in the case of Ribble River Joint Committee *v.* Halliwell. The respondent owned a mill on the river Darwen, and he had from time to time been accustomed to divert the water, which was polluted with

vegetable substances, into a reservoir. The water was impounded in the reservoir, cleared, run off, and then used for condensing purposes. A large deposit was left at the bottom of the reservoir, and from time to time sluice gates were lifted and the deposit was discharged into the river. The matter so discharged was putrid, and it no doubt polluted the river.

The Court of Appeal held that the lawful exercise of the right to impound and divert water, which was protected by Section 17 of the Act of 1876, necessarily implied a right to return the water after it had been used for the purposes for which such right of impounding and diverting was so exercised; and that if, by the impounding, solid matter which was brought down in suspension by the stream was allowed to settle and become putrid, the return of the water, together with such putrid matter, was not an offence under Section 2 of the Act.

265. In the Mersey and Irwell Joint Committee Act, 1892, the prohibition against the putting of solid matters into a stream is extended to "sludge"; but it is provided that no person shall be deemed to have committed an offence against the Act for constructing in or across any "river or stream any . . . dam . . . which but for the passing of the Act he would have a legal right to construct," or "for putting into any such river or stream any sand or gravel or other natural deposit which shall have flowed from or been deposited by the current of any such river or stream."

So far as we are aware, the effect of the Mersey and Irwell Joint Committee Act has not been determined by the High Court; but it was stated by Mr. Tatton, then Chief Inspector of the Joint Committee, that proceedings had been taken under the Act in seven cases against millowners on polluted streams for sludging out mill dams, and that convictions were obtained in all these cases.

Tatton, 20305.

266. The West Riding of Yorkshire Rivers Act, 1894, follows closely the Mersey and Irwell Act, but is, if anything, somewhat stronger. For in addition to "sludge," the West Riding of Yorkshire Act expressly mentions "any rubbish or any deposit in a reservoir, mill dam, water lodge, or pond," as amongst the solid matters which may not be put into a river; and, while it contains the proviso that no person shall be deemed to have committed an offence for putting into a river or stream any sand or gravel or other natural deposit which shall have flowed from or been deposited by the current of the river or stream, it further provides that the sand or gravel or other natural deposit so put back into the stream shall not interfere with the due flow of or pollute the waters of such river or stream.

The West Riding Act has been before the High Court in the case of West Riding of Yorkshire Rivers Board *v.* Goldthorpe and another, which was an appeal by the Rivers Board from the decision of the Quarter Sessions dismissing a case in which a millowner was proceeded against for putting solid matter into a stream. From the report in *The Times* of June 9th, 1898, we gather that the process of the respondents was to collect in the mill dam the water that worked the mill by reason of which a deposit was created. Periodically this deposit was shovelled out into the stream and allowed to be washed down. Evidence was given that as much as 300 tons in one day was thus sent down, and a sample of dark coloured water was put in in evidence. The Court held that the section of the Act prohibiting the putting of solids into a stream did not apply to "cleaning out" a natural deposit of a mill dam. Day, J., stated "that was a natural deposit ordinarily associated with a mill pond when the water was torpid for a certain time. This was not an offence under the section, and, if it were, it would come within the exception."

We may also refer to another action under the West Riding of Yorkshire Rivers Act, viz., West Riding of Yorkshire Rivers Board *v.* Rawsons (1903). The respondents were the owners and occupiers of a mill situated on the bank of a river. Adjoining the mill was a large dam fed by a goit from the river and a tributary stream and having an outlet at the other end into a lower part of the river. The sewage from some 400 houses, besides the treated trade effluents of six mills, entered the river above the dam. Owing to the waters being impounded in the dam, a deposit of mud and sludge had formed in the basin of the dam. The respondents, in order to get rid of the mud-sludge and deposit, opened the sluice at the outlet of the dam and turned the whole of the waters of the river through the dam, while men with spades conveyed and scraped the mud, sludge and deposit into the current so made when it was carried in suspension through the outlet, making the river muddy and unfit for any purpose.

It was held that the respondents had committed no offence under the Act. In the course of his judgment, Wills, J., stated, "under the Act applicable to the present case the sludge is prohibited from being sent out, but, by reason of what has been done, the sludge before anything has been sent out has ceased to be sludge, or has been converted into a very mild decoction." This had reference to the fact that a sample of the water taken at the outlet during the sludge operations was analysed and found to consist of slightly over 99½ per cent. of liquids and less than half per cent. of solids in suspension.

267. It was clearly the intention of the two Rivers Boards, in promoting their special Acts, to obtain power to prevent millowners from turning into the river the solid matters which had been deposited in mill dams, and it was urged by some of the witnesses that the general law should be altered so as to prohibit the scouring out of the sludge into the river, save perhaps in exceptional cases, and that the manufacturer should be required to remove the sludge on to land. Mr. Maclean Wilson, representing the West Riding of Yorkshire Rivers Board, stated that, on the whole, this was the more common practice in the West Riding, and that therefore it must be regarded as a financially practicable method to adopt. Mr. Tatton, Chief Inspector of the Mersey and Irwell Joint Committee, and Mr. Halliwell, Chief Inspector of the Ribble Joint Committee, expressed a similar view.

Somerville, 20251. Tatton, 20286–7, 20318–9. Halliwell, 20503–5. Wilson, 23918–21, 23939–44, 23939–42. Tatton, 20331–2. Halliwell, 20505–6.

On the other hand, Mr. Hughes, representing the Millowners' Association of the River Don, contended that the cost of removing the sludge on to land would in some cases be absolutely prohibitive, and this view was supported by the evidence of Mr. Rawson, a millowner. It was further pointed out that in some cases the situation of the mill dam would render it impracticable to remove the sludge on to land.

20124. 20183–99. Rawson, 20184–6 Halliwell 20515–7.

268. We are satisfied that the discharge of sludge from mill dams into the river, at more or less lengthy intervals of time, in some cases gives rise to serious evils. While the river could itself deal with the suspended matters as they flow down from day to day, it cannot cope with the accumulation of such matters when these are discharged altogether over a short period.

At the same time it must be remembered that in numerous case millowners have had the unrestricted right for many years to empty the sludge from their dams into the river, and that any undue interference with this right might seriously affect industries.

Looking to all the circumstances, and having regard to the evidence given on behalf of millowners, we do not consider that the practice of sludging mill dams by turning the accumulations into the stream should be absolutely prohibited by law in every case without regard to the local circumstances. We are of opinion, however, that in most cases it would be financially practicable for the millowner to remove the sludge on to land or to adopt some other means of disposing of it, and in such cases the millowner should not be allowed to turn it into the stream if, by so doing, a nuisance would be caused.

Recommendation.

269. We recommend that in any case in which the Rivers Board should be of opinion that the sludging of a mill dam by turning the accumulated sludge into the stream would give rise to nuisance, and that it would be financially practicable for the mill owner to adopt some other method of cleansing the dam, the Rivers Boards should be empowered, by notice, to direct the millowner not to turn the sludge into the stream.

It should be provided that any millowner deeming himself aggrieved by such a direction, might, within some fixed period, appeal to the Central Authority. The decision of the Central Authority should be final.

Should any cases arise in which it is important that the sludge should not be turned into the stream, but in which the Rivers Board are of opinion that the cost of adopting any other method of cleansing the dam would be prohibitive to the millowner, we recommend that the Rivers Board should be empowered to represent the case to the Central Authority, and that the Central Authority should be empowered, after due inquiry, to direct that the sludge shall not be turned into the stream. If the Central Authority should be satisfied that the cost of adopting some other method of cleansing the dam would be greater than the millowner could be reasonably called upon to bear, they should be empowered to direct that a portion of the cost should be borne by the local authorities whose districts would be benefited.

PART V.—GENERAL.

EFFECT OF TRADE EFFLUENTS ON SEWAGE PURIFICATION.

270. All the trade effluents of which we have had experience interfere with or retard processes of purification to some extent, but we are not aware of any case where the admixture of trade refuse makes it impracticable to purify the sewage either upon land or by means of artificial processes, although in certain extreme cases special processes of preliminary treatment may be necessary.

In the following cases, which we have investigated more or less fully, some modifications have had to be adopted in consequence of the presence of trade refuse.

Burton-upon-Trent.—Brewery refuse.

Here the sewage consists mainly of brewery refuse, the sewage proper constituting only about one-fifth part of the whole. We are not aware whether artificial processes of treatment have been tried with the Burton sewage; but, for its treatment on land, the addition of a very large quantity of lime has been found necessary (40 to 50 grains per gallon), otherwise the decomposition of the sewage gives rise to the production of much sulphuretted hydrogen, causing great nuisance. With carefully regulated addition of lime, treatment on land appears to be successful in producing a good effluent.

Bradford.—Wool-scouring liquor.

The sewage of Bradford contains a large proportion of wool-scouring liquors, which have the effect of making it abnormally alkaline and very greasy. A special preliminary process of precipitation has therefore been found necessary, viz., the "cracking" of the sewage with sulphuric acid. The fats which are thus set free are extracted from the precipitated sludge by pressing hot, and by distillation of this pressed sludge under reduced pressure. The precipitation liquor after the addition of sulphuric acid can be successfully treated on percolating filters at rates of from 50 to 100 gallons per cube yard per day, notwithstanding that it is often distinctly acid as it goes on to the filter. It may be added that the effluent from the filters is usually neutral or slightly alkaline.

Rochdale.—Wool-scouring liquor, waste liquor from fellmongers, rubber-recovery waste.

At Rochdale, as at Bradford, the sewage is often rendered very alkaline and greasy by the discharge of wool-scouring liquor. At such times sulphuric acid in addition to alumino-ferric is used as a precipitant; otherwise the tank liquor obtained is unsatisfactory and badly settled. The sewage after precipitation is successfully treated, either upon filters, or upon land.

It is interesting to note that the strong alkaline sewage at Rochdale can be successfully treated, without any neutralisation, by septic tanks, followed by Whittaker percolating filters.

Wolverhampton.—Waste liquors from galvanising works.

Owing to the discharge of the "used-out" liquors and wash water (which contain a large quantity of ferrous iron in acid solution) from the vats at the galvanising works in the town, the Wolverhampton sewage is often mixed with such a large quantity of this liquor that it is then necessary to increase the quantity of lime which

is used as a precipitant in order to obtain good settlement in the tanks. If sufficient lime is added, the iron in the sewage helps the precipitation. The tank liquor is successfully treated over land, and it has also been shown, by experiment, to be easily amenable to treatment on bacteria beds.

There are many similar cases; but those cited are, perhaps, sufficient to show that trade effluents may render necessary modifications in the ordinary processes of purification.

271. These cases may, we think, be regarded as more or less exceptional. Usually we find that the amount of trade effluent is not sufficiently large to make any material modification of the *process* necessary, though of course the increase in volume of the sewage to be treated may necessitate an enlargement of the filtering area. The following are cases of this kind :—

Birmingham.—Various manufacturing liquors.

The Birmingham sewage, notwithstanding the considerable proportion of various manufacturing waste liquors which it contains, can be successfully treated upon land or upon artificial filters, after ordinary preliminary settlement and septic tank treatment.

Manchester.—Various manufacturing wastes, including many tar products.

Here part of the sewage is being successfully treated on a large scale by means of septic tanks and contact beds.

Leeds.—Wool fibre, dye waste, tannery and iron liquors.

The fibrous nature of the suspended matter in the Leeds sewage and the amount of finely divided and colloidal iron compounds which it contains seem to be the main causes which render the settlement—either by septic tank treatment or sedimentation, or even by precipitation—more difficult, and the danger of filter clogging much more serious, than would be the case if these waste products were absent. The trade effluents in general also seem to have the effect of inhibiting, to some extent, the action of the nitrifying organisms in the biological oxidation processes at Leeds, for it has been noticed that filters take an exceptionally long time to mature there.

The experiments at Leeds, however, have shown that it is possible to produce good effluents by various processes, and that—with careful selection of the materials—clogging can be prevented long enough to make it practicable to treat the sewage by artificial filtration.

Maidstone.—Brewery and tannery waste.

The Maidstone sewage is frequently mixed with large quantities of the waste liquors from breweries and tanneries. At such times the liquid resulting from the tank treatment after precipitation with lime is organically stronger and less well settled than at other times. The trade effluents at Maidstone also appear to have the effect of increasing the nuisance from the tanks, for it has been noticed that when these liquors are present the smell is much greater. Experiments, worked partly under our observation for this special purpose, have shown that the sewage can be purified to the extent of 88 per cent., calculated on the "oxygen absorbed" in four hours, by double contact filtration, without preliminary treatment in tanks for the settlement of the solids, although only a small quantity (23·7 gallons) can be filtered per cube yard per day.

Yeovil.—Waste liquors from tanneries.

At Yeovil, closed septic tanks and double contact beds appear to be successful in treating a sewage which is often mixed with a large proportion of tannery liquor.

Here the effect may be to require a more frequent cleansing of the tanks and possibly of the filter beds. We have not watched the plant continuously.

York.—Tannery waste and waste-waters from a confectionery works.

After septic tank treatment the York sewage can be successfully treated upon percolating filters at a rate of something like 150 gallons per cube yard per day.

There are a number of such cases, and, indeed, the great majority of sewages from towns with populations from 5,000 upwards are mixed with small proportions of manufacturing wastes. Generally, therefore, we are satisfied that the character and proportion of the trade effluent or effluents in the sewage are not such as seriously to affect any process of purification, though in some cases where it is present in large proportion, or is of a specially refractory character, special means have to be taken to counteract its influence.

At many of the places which we have visited (for example, Birmingham, Bradford, Burton, Burnley, Huddersfield, Leeds, Manchester) the difficulties arising from the admixture of trade effluent with the sewage have been largely overcome as the result of experiments, which have been conducted under the supervision of skilled scientific advisers resident upon the works.

272. Our further experience strengthens the view which we expressed in our Third Report, that, as a general rule, trade effluents should be allowed to enter the sewers, but that the local authority should be given power to require that their admission should be subject to regulation.

NUISANCE FROM SMELL AT SEWAGE WORKS.

273. All sewage works are liable, at times, to give off unpleasant smells, and they should, therefore, be situated away from dwelling houses, wherever this is practicable.

The nuisance is apt to be considerably greater where the sewage contains brewery refuse in any quantity; but, on the other hand, the presence of some trade effluents, such, *e,g.*, as iron salts or tarry matters, tends to render the process of purification less offensive.

The extent of the risk of nuisance depends, however, not only on the character of the sewage, but also on the method of treatment adopted.

Tank Treatment.

274. Septic tank treatment is likely to be more offensive than chemical precipitation or simple sedimentation. During sludging operations all tanks are usually offensive; but septic tanks—unlike other tanks—may give off sulphuretted hydrogen, and probably small quantities of offensive organic sulphides, at other times.

By covering over septic tanks and the feed channels to the filters, the risk of nuisance from the tanks themselves during the period of working is greatly lessened, but the liquor issuing from septic tanks contains a larger amount of sulphuretted hydrogen than other tank liquors, and its subsequent filtration may, therefore, give rise to more nuisance.

Filters.

275. The exposure of a foul smelling liquid to the air is necessarily accompanied by risk of nuisance, and if such a liquid, in the process of distribution, is divided up into small drops or jets, it is obvious that the smell will be greatly intensified.

For these reasons percolating filters are more likely to give rise to nuisance than contact beds, if the liquid to be treated contains offensive gases.

In some cases, septic tank liquor can be treated upon percolating filters without much risk of nuisance, but where the liquor is derived from a strong domestic sewage or a domestic sewage containing brewery or tannery waste, and especially if it is sprinkled or sprayed upon percolating filters, serious smell may occur in the neighbourhood of the works.

At the following places where septic tank liquor is sprinkled upon percolating filters, there is usually a considerable smell in the proximity of the filters :—

Accrington	Strong domestic sewage.
Dorking	Domestic sewage of about average strength.
Guildford	Very strong domestic sewage containing brewery waste.
Dorchester	Domestic sewage containing brewery waste.

On the other hand the same process does not give rise to any serious complaint at :—

Birmingham	Strong sewage containing much manufacturing waste, which includes salts of iron.
Huddersfield	Rather weak sewage containing much manufacturing waste, including salts of iron.
Leeds	Rather weak sewage containing much manufacturing waste, including salts of iron.
Hanley	Weak sewage containing a small proportion of manufacturing waste.

Where fresh crude sewage or fresh precipitation liquor is treated upon percolating filters, there is much less danger of nuisance. This is exemplified at the following places :—

Crude Sewage :

Hendon	Domestic sewage of average strength.
Leeds	Rather weak sewage containing much manufacturing waste.

Settled Sewage :

Huddersfield - -	Rather weak sewage containing much manufacturing waste.
Leeds - - -	Rather weak sewage containing much manufacturing waste.
Market Drayton -	Very strong slopwater sewage.

Precipitation Liquor :

Kingston - - -	Domestic sewage containing a small proportion of trade waste.
Dorking - - -	Domestic sewage of about average strength.
Chorley - - -	Domestic sewage of about average strength.
Royton - - -	Domestic sewage.
Normanton - -	Very strong slopwater domestic sewage.
Withnell - - -	Strong domestic sewage, mainly slopwater.

At Horfield, however (strong domestic sewage, partly derived from latrines), where precipitation liquor was distributed by dripping trays upon percolating filters, there was occasionally a very strong local smell upon the works.

276. Our experience leads us to the following general conclusions upon this question:—

That where weak sewage, purely domestic or mixed with manufacturing refuse, is treated either fresh or after chemical precipitation, or even after passing through septic tanks, there is not likely to be any serious smell. If such a sewage contains a small proportion of brewery or tannery waste, however, and is given preliminary treatment in septic tanks, nuisance may possibly arise if the septic liquor is sprinkled or sprayed upon percolating filters.

That where a strong domestic sewage is treated, either fresh or after settlement or chemical precipitation, by sprinkling upon percolating filters, and especially if it is a slopwater sewage, there will not be much danger of nuisance.* On the other hand, if such a sewage is passed through septic tanks, there will be danger of serious nuisance, while if it contains brewery or tannery waste there will be danger of nuisance with any form of preliminary treatment, excepting possibly chemical precipitation.

That with a weak sewage, containing a mixture of trade wastes (especially if iron salts are present), there will be little danger of nuisance, whatever the form of preliminary treatment or final filtration.

That with a strong sewage containing a mixture of trade wastes, there will not be much danger of nuisance, if it is treated by sprinkling upon percolating filters in the fresh state or after simple subsidence or chemical precipitation; but, if it is first passed through septic tanks, there may in some cases be serious danger of nuisance. This was well exemplified in the case of the experimental septic tank at Sheffield, even though the sewage there contained considerable quantities of iron salts.

The risk of nuisance with percolating filters depends to a large extent on the method of distribution adopted, unless the filter is covered in.

277. The following table shows a number of places arranged in the order of "strength" of sewage, side by side with our observations as to nuisance arising from the distribution of the liquid over the filters:—

* This might not hold good in the case of highly ammoniacal sewages.

Place.	Nature of Sewage.	*Calculated strength of sewage.	Nature of preliminary treatment.	Distributor.	Remarks as to smell arising from the distribution.
Places where smell is apparent.					
Rochdale -	Strong domestic sewage, mixed with large quantities of wool-scouring liquor.	203	Septic tank.	Sprinkler.	Considerable smell in neighbourhood of filter.
Caterham -	Very strong domestic sewage, derived mostly from latrines.	195	Septic and "cultivation" tank.	Perforated pipes.	Strong smell in filter house.
Guildford -	Very strong domestic sewage, mixed with brewery waste.	194	Septic tank.	Sprinklers.	Strong smell in neighbourhood of filter.
Accrington -	Rather strong domestic sewage.	121	Septic tanks.	Sprinklers.	Strong smell near filters as a general rule.
Dorking -	Domestic sewage of about average strength.	96	Septic tanks.	Sprinkler.	Strong smell near filters.
Horfield -	Domestic sewage, derived partly from latrines.	88	Precipitation tanks.	Dripping trays.	Occasionally very strong smell near filters.
Knowle -	Domestic sewage.	78	Septic tanks.	Dripping trays.	Occasionally some smell near filters.
Places where little smell is apparent.					
Clifton - -	Very strong slopwater sewage.	247	Settling tanks.	Fine material on surface.	Very little smell from filters.
Normanton -	Very strong slopwater sewage.	235	Precipitation tanks.	Fine material on surface.	Very little smell from filters.
Little Drayton	Very strong slopwater sewage, containing laundry waste.	205	Settling tanks.	Tipping troughs.	Very little smell from filters.
Birmingham -	Strong trade sewage, containing salts of iron.	—	Septic tanks.	Nozzles.	Very little smell from filters.
Leeds - -	Trade sewage, strong as regards suspended matter, but otherwise rather weak.	123	Septic, settling and precipitation tanks.	Sprinklers.	Very little smell from filters.
York - -	Rather weak domestic sewage, but containing tannery waste, etc.	115	Septic tanks.	Sprinklers.	Very little smell from filters.
Hendon -	Domestic sewage of about average strength.	110	No preliminary treatment.	Tipping troughs.	Very little smell from filters.
Chorley -	Domestic sewage of about average strength.	106	Precipitation tanks.	Flushing over fine material on surface.	Practically no smell from distribution.
Dorking -	Domestic sewage of about average strength.	96	Precipitation and settling tanks.	Sprinklers.	Very little smell from filters.
Kingston -	Domestic sewage of about average strength.	94	Precipitation tanks.	Sprinkler.	Practically no smell from distribution.
Salford - -	Trade sewage of about average strength.	—	Precipitation tanks.	Nozzles.	Very little smell from distribution.
Hanley - -	Weak domestic sewage, containing a small proportion of trade waste.	61	Septic tanks.	Sprinklers.	Very little smell from filters.
Prestolee	Very weak slopwater sewage.	28	Septic tanks.	Fine material on surface.	Very little smell from filters.

(* See p. 15 of this report and the memorandum of Dr. McGowan in Appendix IV.)

278. In the whole of our experience with contact beds, we have only observed one case in which any appreciable nuisance arose after the liquor to be treated was in the bed.

In that case the nuisance was, we think, due to overworking, for the smell practically disappeared when the beds were given a short rest.

On the other hand, there is almost always local smell from the channels or feed troughs delivering to a contact bed, when the liquid to be treated possesses a strong smell, and also, in some cases, when the primary bed is being discharged.

At Hampton, during the last year of the treatment of crude sewage upon contact beds, the filling of both primary and secondary beds was attended with local smell. In the case of the primary beds, we think that there would have been serious nuisance if there had been houses in close proximity to the works. In this case, the smell chiefly arose from the settling " bays " constructed on the surfaces of the beds.

At Guildford, Hartley Wintney, Andover, Exeter (Main Works), Ilford, Leeds, Bradford, and Sheffield, we have, on a number of occasions, been aware of considerable local smell arising from feed channels during the filling of contact beds. If steps are taken to obviate this, there is no doubt that contact beds are less liable to give rise to nuisance than any other form of filters.

In connection with the smell which arises from feed channels and distribution pipes, it is of interest to observe that at Ilford and Andover the authorities have recently adopted the plan of covering the channels and laying a few inches of material over the distribution pipes. We understand that this has had the effect of reducing the smell to a very large extent.

An important point which is sometimes lost sight of is that, although the surfaces of contact beds are rich in insect life, it is unusual to see many flies on the beds, whereas percolating filters of coarse or medium material generally swarm with them.

Treatment on Land.

279. Where the soil is fairly porous and the land is not overworked, land treatment of sewage is not, as a rule, offensive.

In certain states of the atmosphere, however, we find that the smell from sewage farms is offensive, and it is therefore important that sewage farms, also, should be kept as far away from dwelling houses as practicable.

Deodorization of Septic Tank Liquors.

280. The use of septic tanks followed by percolating filters, may, in some cases, be the most economical way of treating the sewage, but in view of the greater risk of nuisance from such a combination, it might not be advisable to adopt it in many cases.

The question whether the offensive character of septic tank liquors might be destroyed, arose in the case of Stone, in Staffordshire, where a sewage containing brewery refuse had to be dealt with. In that case it was proposed to overcome the difficulty by the addition to the septic tank liquor of an active chlorine solution, *i.e.*, a solution of alkaline hypochlorite, produced by an electrical process by a company named " Oxychlorides, Limited."

The addition of this chlorine solution clearly lessened the offensive smell of the septic tank liquor, but the question was raised whether it might not also interfere with the subsequent oxidation of the sewage by filtration.

For the purpose of testing this by experiment, two identical percolating filters were provided at the Guildford sewage works, and these were kept under observation for several months by Mr. Carter, Assistant Chemist to the Commission. On to one of these filters was run septic tank liquor alone; on to the other, the same tank liquor, in the same amount, but mixed with varying quantities of the hypochlorite solution.

The results of these experiments showed :—

1. That "35* per cent. to 50 per cent. treatment" with the hypochlorite solution is sufficient to do away with the offensive sulphuretted hydrogen smell of the Guildford septic tank liquor, leaving in its place a comparatively inoffensive odour of spent bleach and fresh sewage.

2. That the addition of this quantity of "oxychloride" in no way interferes with the efficiency of the filter. Indeed, it rather adds to it, by helping to keep down an excess of grey growths on the top of the filter.

3. That a very much larger quantity of oxychloride *may* be added, without any danger to the filter. In other words, there is a large margin of safety, so far as regards the accidental addition of too much oxychloride. Somewhere between "200 per cent. and 500 per cent. treatment" appears to be the limit of the quantity of oxychloride which can be added with safety.

A number of bacteriological examinations were also made in connection with the experiments, and we ascertained that a dose of oxychloride *more* than sufficient to remove a sulphuretted hydrogen smell and kill *B. coli* in the liquid to be treated may be used without prejudice to the purifying ability of a *mature* percolating filter.

A summary of the experiments is given in the accompanying table, and a detailed Report upon them in Appendix IV.

* As to the meaning of this term *see* Mr. Carter's Report, Appendix IV.

Date and Duration of Experiment.	% Treatment	Effect of Treatment as regards Smell of Tank Liquor.	Effect of Treatment as regards Purification by the Filter.	Nitric Nitrogen. Parts per 100,000. Effluent from Untreated Tank Liquor. †	Nitric Nitrogen. Parts per 100,000. Effluent from Treated Tank Liquor. †
				Average.	Average.
Nov. 22nd to Dec. 5th, 1906 (14 days).	25 %	Tank liquor rendered much less offensive, owing to the destruction of about four-fifths of the total sulphuretted hydrogen present.	Quality of the effluent unaffected. The effluent had a slight spent bleach liquor odour.	1·41—2·41=2·07 (8)	1·33—2·74=2·15 (8)
Dec. 6th to 10th, 1906 (5 days).	35 %	This increase of dose was too small to make any marked difference from the 25 % treatment. The tank liquor still possessed a slight septic odour, the sulphuretted hydrogen not being entirely eliminated.	Quality of the effluent unaffected.	1·95—1·98=1·97 (3)	1·95—2·00=1·97 (3)
Dec. 11th to 21st, 1906, and Dec. 31st, 1906, to Jan. 13th, 1907 (25 days).	50 %	This dose completely destroyed all the sulphuretted hydrogen present. The tank liquor possessed a slight fresh sewage smell with an accompanying spent bleach liquor odour, and was not offensive.	Quality of the effluent unaffected.	1·25—2·78=2·13 (15)	1·29—3·63=2·23 (15)
* Feb. 15th to May 13th, 1907 (87 days).	100 %	With this dose there was an excess of oxychloride in the tank liquor going on to the filter. The sewage smell was masked by the spent bleach liquor odour. The average excess of oxychloride was equal to 1·00 parts of available chlorine per 100,000.	Taking the figures for analysis over the whole time, there was very little difference between the quality of the two effluents. This experiment was started in very cold weather, and at first the effluent from the filter taking the treated liquor was inferior in quality to the effluent from the filter taking the untreated liquor. As the weather became warmer, both effluents improved.	0·60—5·82=2·38 (66)	0·21—5·81=2·59 (66)
May 14th to 30th, 1907 (17 days).	200 %	The tank liquor was bleached considerably by this dose.	Quality of the effluent unaffected.	4·10—6·21=4·84 (13)	4·10—6·46=4·92 (13)
May 31st to June 10th, 1907 (11 days).	500 %	This dose bleached the tank liquor to a pale yellowish colour. The average excess of oxychloride amounted to about 12–16 parts of available chlorine per 100,000.	The quality of the effluent was appreciably affected by this dose, both as regards appearance and the amount of Nitric Nitrogen.	4·62—5·98=5·26 (10)	2·90—5·05=4·00 (10)
June 11th to July 12th, 1907 (32 days).	1,000 %	The tank liquor was completely bleached by this dose and possessed a strong spent bleach liquor odour, owing to the large excess of oxychloride (about 30 parts of available chlorine per 100,000).	The quality of the effluent was immediately affected by this dose, the Nitric Nitrogen being reduced by about 50 per cent. In a fortnight it had disappeared entirely and the effluent was very thick and turbid in appearance, and on testing gave a reaction for available chlorine.	4·22—5·85=4·91 (14)	0·00—2·70=1·17 (14)

* From March 5th, 1907, the conclusions have been based on data supplied by Mr. Fieldhouse, Manager at Guildford for Oxychlorides, Ltd.
† Figures in brackets represent the number of samples analysed.

The Oxychloride Company has furnished the following figures as representing the working cost of deodorising 1,000,000 gallons of septic tank liquor by the addition of 6 gallons, 8·4 gallons, and 12 gallons of strong oxychloride, respectively, per 100,000 gallons of liquor :—

Amount of Oxychloride added.	Working cost per million gallons.	
	s.	d.
6 gallons per 100,000 gallons - - - -	9	3
8·4 „ „ „ - - - -	12	2
12 „ „ „ - - - -	18	6

The capital cost of the plant would be the same in each case. For the Guildford sewage, this was calculated to be £1,220.

281. Of course, there are other ways of providing chlorine, if it should be found that this is the best body to use for the purpose of destroying the offensive character of septic tank liquor.

Our own experiments have shown that the offensive character of Dorking septic tank liquor can be destroyed by the addition to it of 3 grains of lime per gallon. We have also found that the liquor, so treated, could, after a short settlement, be filtered at a considerably increased rate.

Generally, we may say that the risk of nuisance at a sewage works may be considerably lessened by careful selection of the method of treatment and careful attention to details; and that by the adoption of special precautions, methods of treatment, which ordinarily are accompanied by somewhat serious smell, may be rendered almost inoffensive.

SOME OBSERVATIONS ON THE CHOICE OF A METHOD OF SEWAGE TREATMENT.

General.

282. The selection of a method of sewage disposal, and the settlement of details in connection with any method which it is proposed to adopt, should depend primarily on local conditions, and we only propose to indicate in a general way what, in our opinion, should be the guiding considerations.

In a later part of this Report,* we have expressed the view that the degree of purification which should be required in any particular case should depend on local circumstances, and the question which a local authority would have to determine would be in what way the sewage could be most economically purified to the extent necessary. If a sufficient quantity of good land, to which the sewage can flow by gravitation, can be purchased for about £100 an acre, land treatment would, we think, usually be the cheapest method to adopt. Or, if the case were one in which it was necessary to obtain a high class effluent, it might be cheaper to pay a somewhat higher price for good land, rather than to adopt artificial treatment, because effluents obtained from the treatment of sewage on artificial filters, as usually carried out in practice, are generally distinctly inferior to those obtained by the treatment of sewage on good land, and some addition to the ordinary artificial plant would therefore be required. On good land, a sewage of average strength, from which the major portion of the suspended solids have been eliminated by tank treatment, can be treated at about the rate of 30,000 gallons per acre per day, with the production of a high class effluent. If the land available were of only medium quality, capable, say, of treating only half this quantity, its use might still be economical, if it could be acquired at about £50 an acre.

In cases where only clay land was available, we think that it would generally be cheaper and more satisfactory to provide artificial filters.

In considering the question whether land or artificial treatment should be adopted, the situation and levels of the land available are, of course, important factors. And whatever system is adopted, it is essential that the works should be so situated as to be capable of extension.

Selection of an Artificial Process.

283. As regards the selection of an artificial process, the following are the broad generalisations at which we have arrived :—

Tank Treatment.

It has been shown in another section of our Report that, given conditions favourable to each process, there is little difference as regards cost between any of the different forms of tank treatment when the cost of the subsequent filtration is taken into account. For this reason, the selection of the preliminary process should depend mainly upon local circumstances and upon the facilities offered for the disposal of sludge.

If the circumstances were such that considerable quantities of sludge could be easily and effectively disposed of, say, as wet sludge by sending to sea or by trenching in soil, or as pressed cake by sale or gift to farmers, it would probably be best and cheapest to adopt a preliminary process which removed as much of the suspended matter as possible from the sewage. If, on the other hand, it were imperative to have as little sludge and as few sludging operations as possible, then septic tanks or continuous flow settling tanks might be cheaper. The size of the place and the question of smell † are also factors of primary importance in the selection of the preliminary process.

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* *See* section of this Report on Standards, p. 217.

† *See* preceding section, "Nuisance from Smell."

CLASS I.

Typical Analysis of Sewage from a water-closet town with a water supply of 25 to 30 gallons a head. Separate system of sewers.

Typical Analysis of Sewage from a slop-water town, having few water-closets, where the water supply is about 10 to 15 gallons a head, and where the sewers are on the partially separate system.

Strong or Very Strong Sewage.

Ammoniacal nitrogen	9·0
Oxygen absorbed in 4 hours	17·0
Suspended solids	40·0

Strength 160 to 170.

Ammoniacal nitrogen.	Oxygen absorbed in 4 hours.	Suspended solids.
7·5	20	40

Strength 175 to 200.

Ammoniacal nitrogen	6·0
Oxygen absorbed in 4 hours	25·0
Suspended solids	40·0

Strength 200 to 230.

Chemical precipitation and quiescent settlement for 2 hours.

Precipitation Liquor.

Ammoniacal nitrogen	7·0
Oxygen absorbed in 4 hours	8·0
Suspended solids	2 to 5

Strength 90.

Chemical precipitation and 8 hours' continuous flow settlement.

Precipitation Liquor.

Ammoniacal nitrogen	7·0 to 7·5
Oxygen absorbed in 4 hours	9·0
Suspended solids	8·0

Strength 95 to 100.

Quiescent settlement for 2 hours.

Settled Sewage.

Ammoniacal nitrogen	7·0 to 7·5
Oxygen absorbed in 4 hours	10·0
Suspended solids	10·0

Strength 100 to 105.

Continuous flow settlement for 15 hours.

Settled Sewage.

Ammoniacal nitrogen	7·0 to 7·5
Oxygen absorbed in 4 hours	12·0
Suspended solids	15 to 20

Strength 120.

Septic tanks. 24 hours' continuous flow.

Septic Tank Liquor.

Ammoniacal nitrogen	8·0 to 8·5
Oxygen absorbed in 4 hours	13·0
Suspended solids	15·0 to 20·0

Strength 130.

Effluents.

	Double contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard.	6 gallons. (2½ fillings)	150 gallons.	100 gallons.	25,000 to 30,000 gallons. per acre per day. (5 to 6 gallons. per sq. yd.).
Ammoniacal nitrogen	2·0	2·0	2·0 to 3·0	0·25
Nitric nitrogen	1·5	2·0	3·0	1·5
Oxygen absorbed in 4 hours	3·0	3·0	2·5	0·3 to 0·5
Suspended solids	2·0	4·0 to 5·0	2·0 to 3·0	Possible traces of growth, washed out from drains.

Variable effluents, sometimes putrescible.

Effluents.

	Double contact beds.	Percolating filters of coarse material (deep.)	Percolating filters of medium material (shallow.)	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	50 gallons. (2 fillings)	100 gallons.	75 gallons.	25,000 gallons. per acre (6 gallons. per sq. yd.).
Ammoniacal nitrogen	2·0	2·5	2·5	0·25
Nitric nitrogen	1·5	2·0	2·0 to 3·0	1·5
Oxygen absorbed in 4 hours	3·0	3·0	2·5	0·3 to 0·5
Suspended solids	2·0	6·0	5·0	Possible traces of growth, washed out from drains.

Variable effluents, sometimes putrescible.

Effluents.

	Triple contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material (deep).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	40 gallons. (4 fillings)	75 gallons.	35 gallons.	20,000 gallons. per acre per day (4 gallons. per sq. yd.).
Ammoniacal nitrogen	1·0	1·0	0·5	0·25
Nitric nitrogen	2·0 to 2·5	3·0	4·0	1·5
Oxygen absorbed in 4 hours	1·5	3·0	2·5	0·3 to 0·5
Suspended solids	Trace	6·0 to 8·0 and more.	5·0	Possible traces of growth, washed out from drains.

Fine material in tertiary beds.
Rate of filtration could not be doubled in wet weather.

Effluents.

	Triple contact beds.	Percolating filters of coarse material (deep).	Percolating filter of fine material (deep).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day	20 gallons. (3 fillings).	50 gallons.	25 gallons.	20,000 gallons. per acre per day (four gallons. per sq. yd.).
Ammoniacal nitrogen	0·5	1·0	0·75	0·25
Nitric nitrogen	2·5 to 3·0	3·5	4·0	1·5
Oxygen absorbed in 4 hours	1·5	3·0 to 4·0	2·5 to 3·0	0·3 to 0·5
Suspended solids	Trace	6 to 10 and more.	5 to 7	Possible traces of growth from drains.

Fine material in tertiary beds.

Beds would choke on surface every 2 years.
We have had no experience of shallow filters of fine material, dealing with a strong liquor of this kind.

Effluents.

	Triple contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material (deep).	Good land.
Rate of filtration per cube yard per day	20 gallons. (3 fillings)	30 gallons.	25 gallons.	—
Ammoniacal nitrogen	0·5	1·0	0·75	Considerable danger of nuisance from smell.
Nitric nitrogen	2·5 to 3·0	3·5	4·0	—
Oxygen absorbed in 4 hours	1·5	3·0 to 4·0	2·5 to 3·0	—
Suspended solids	Trace	6 to 10 and more.	5 to 7	—

Fine material in tertiary beds.

Beds would choke on surface every 2 years.
We have had no experience of shallow filters of fine material, dealing with a strong liquor of this kind.

NOTES.—(1) The numbers given for "strength" of Sewage represent *approximately* the parts by weight of oxygen required to oxidize 100,000 parts.
(2) "Oxygen absorbed in 4 hours" means oxygen absorbed in 4 hours at 27° C. (80° F.) from an eighth normal solution of permanganate of potash (3·94 grms. per litre), rendered acid with dilute sulphuric acid.
(3) All figures of analysis are stated in parts per 100,000.
(4) By a "deep" filter we mean one of 5 to 6 feet and upwards in depth; by a shallow filter one which is below 5 feet in depth and usually about 3 feet. It would probably be inadvisable at the present time to build sewage filters of a less depth than 2 feet 6 inches.
(5) At first sight it may seem curious that the same figures of analysis should be given for the land effluents of this Class. It has, however, to be remembered that the mechanical straining effect of land is such that all liquors derived from the same sewage must necessarily be brought more or less into line, and, further, that volume of sewage is a more important factor in land treatment than strength.
(6) The figures of analysis for effluents refer to the effluents including their suspended solids.

This sewage would be derived from a water-closet town, where the sewers were on the partially separate or the combined system, where the water supply was about 30 gallons per head, and where a moderate quantity of subsoil water gained access to the sewers.

CLASS II.

Sewage of about Average Strength.

Ammoniacal nitrogen.	Oxygen absorbed in 4 hours.	Suspended solids.
4·0	10 to 12	28 to 30

Strength 100.

Chemical precipitation and quiescent settlement for 2 hours.

Precipitation Liquor.

Ammoniacal nitrogen	3·5 to 4·0
Oxygen absorbed in 4 hours	4·5
Suspended solids	1 to 4

Strength 50.

Effluents.

	Single contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	150 galls. (3 fillings)	200 galls.	200 galls.	30,000 to 40,000 galls. per acre per day (6 to 8 galls. per sq. yd.).
Ammoniacal nitrogen	2·0	1·0	1·5	0·5
Nitric nitrogen	0·5	2·0	2·5	0·5
Oxygen absorbed in 4 hours	2·0	1·5	1·5	0·8
Suspended solids	1·0	3·0 and more	2·0	Practically none.

Fine material. Variable effluents, sometimes putrescible.

Chemical precipitation and 3 hours' continuous flow settlement.

Precipitation Liquor.

Ammoniacal nitrogen	3·7 to 4·0
Oxygen absorbed in 4 hours	5·5
Suspended solids	3 to 6

Strength 60.

Effluents.

	Double contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping.)
Rate of filtration per cube yard per day.	80 galls. (3 fillings)	150 galls.	100 to 150 galls.	30,000 to 40,000 galls. per acre per day (6 to 8 galls. per sq. yd.)
Ammoniacal nitrogen	1·0	0·75	0·5	0·5
Nitric nitrogen	1·5	2·0	2·5 to 3·0	0·5
Oxygen absorbed in 4 hours	1·5	1·5	1·0	0·8
Suspended solids	2·0	3·0 and more.	2·0	Practically none.

Quiescent settlement for 2 hours.

Settled Sewage.

Ammoniacal nitrogen	3·8
Oxygen absorbed in 4 hours	6·5
Suspended solids	5·8

Strength 70.

Effluents.

	Double contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping.)
Rate of filtration per cube yard per day.	80 galls. (3 fillings)	150 galls.	100 galls. per cube yd.	25,000 to 30,000 galls. per acre per day (5 to 6 galls. per sq. yd.)
Ammoniacal nitrogen	1·0	0·5	0·75	0·5
Nitric nitrogen	1·5	2·5	2·5	0·5
Oxygen absorbed in 4 hours	1.5	1·5	1·0	0·8
Suspended solids	2·0	4·0 and more.	2·0	Practically none.

Continuous flow settlement for 15 hours.

Settled Sewage.

Ammoniacal nitrogen	3·8
Oxygen absorbed in 4 hours	7·5
Suspended solids	10 to 15

Strength 80.

Effluents.

	Double contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material.	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	50 galls. (2 fillings)	100 galls.	Filters would clog unless rate of filtration were very slow, say 30 to 50 gallons per cube yd.	25,000 to 30,000 galls. per acre per day (5 to 6 galls. per sq. yd.)
Ammoniacal nitrogen	0·5	0·75		0·5
Nitric nitrogen	2·0	2·5		0·5
Oxygen absorbed in 4 hours	1·0	3·0		0·8
Suspended solids	2·0	6·0 and more.		Practically none.

Septic tanks. 24 hours' continuous flow.

Septic Tank Liquor.

Ammoniacal nitrogen	4·5 to 5·0
Oxygen absorbed in 4 hours	7·5
Suspended solids	10 to 15

Strength 80.

Effluents.

	Double contact beds.	Percolating filters of coarse material (deep).	Percolating filters of fine material.	Good land.
Rate of filtration per cube yard per day.	50 galls. (2 fillings)	100 galls.	Filters would clog unless rate of filtration were very slow, say 30 to 50 galls. per cube yd.	Danger of nuisance from smell.
Ammoniacal nitrogen	0·5	0·75	"	"
Nitric nitrogen	2·0	2·50	"	"
Oxygen absorbed in 4 hours	1·0	3·0	"	"
Suspended solids	2·0	6·0 and more.	"	"

NOTES.—(1.) The numbers given for "strength" of sewage represent *approximately* the weights of oxygen required to oxidize 100,000 parts.

(2.) "Oxygen absorbed in 4 hours" means oxygen absorbed in 4 hours at 27° C (80° F) from an eighth-normal solution of permanganate of potash (3·94 grms. per litre), rendered acid with dilute sulphuric acid.

(3.) All figures of analysis are stated in parts per 100,000.

(4.) By a "deep" filter we mean one of 5 to 6 feet and upwards in depth; by a "shallow" filter, one which is below 5 feet and usually about 3 feet. It would probably be indivisable at the present time to build any sewage filter of less depth than 2 feet 6 inches.

(5.) At first sight it may seem curious that the same figures of analysis should be given for the land effluents in this class. It has, however, to be remembered that the mechanical straining effect of land is such that all liquors derived from the same sewage must necessarily be brought more or less into line, and, further, that volume of sewage is a more important factor in land treatment than strength.

(6.) The figures of analysis for effluents refer to the effluents including their suspended solids.

This sewage would be derived from a water-closet or slop-water town, where the sewers were on the combined or partially separate system, where the water supply was about 25 to 30 gallons a head, and where much sub-soil water gained access to the sewers.

CLASS III.

Weak Sewage.

Ammoniacal nitrogen.	Oxygen absorbed in 4 hours.	Suspended solids.
2·5	7 to 8	20

Strength 60.

Chemical precipitation and quiescent settlement for 2 hours.

Precipitation Liquor.

Ammoniacal nitrogen	2·0
Oxygen absorbed in 4 hours	3·0
Suspended solids	1 to 3

Strength 30.

Effluents.

	Single contact beds.	Percolating filters of coarse material.	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	200 galls. (4 fillings) ...	200–300 galls. ...	300 galls. ...	30,000 to 40,000 galls. per acre per day (6 to 8 galls. per sq. yd.).
Ammoniacal nitrogen	0·75 ...	0·50 ...	0·50 ...	0·2
Nitric nitrogen	0·5 to 0·75 ...	1·0 ...	1·0 ...	0·5 to 1·0
Oxygen absorbed in 4 hours	0·75 ...	1·0 ...	0·75 ...	0·4
Suspended solids	1·0 ...	2·0 to 3·0 and more at times. ...	1·0 ..	None.
	Fine material. The rate of filtration could not be doubled in times of storm. Variable effluent.			

Chemical precipitation and 8 hours' continuous flow settlement.

Precipitation Liquor.

Ammoniacal nitrogen	2·0
Oxygen absorbed in 4 hours	3·0 to 3·5
Suspended solids	2 to 5

Strength 30 to 35.

Effluents.

	Single contact beds.	Percolating filters of coarse material.	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	200 galls. (4 fillings) ...	200–300 galls. ...	250–300 galls. ...	30,000 to 40,000 galls. per acre per day (6 to 8 galls. per sq. yd.).
Ammoniacal nitrogen	0·75 ...	0·50 ...	0·50 ...	0·2
Nitric nitrogen	0·5 to 0·75 ...	1·0 ...	1·0 ...	0·5 to 1·0
Oxygen absorbed in 4 hours	0·75 ...	1·0 ...	0·75 ...	0·4
Suspended Solids	1·0 ...	2·0 to 3·0 and more at times. ...	1·0 ...	None.
	Fine material. The rate of filtration could not be doubled in times of storm. Variable effluent.			

Quiescent settlement for 2 hours.

Settled Sewage.

Ammoniacal nitrogen	2·0
Oxygen absorbed in 4 hours	3·5
Suspended solids	4 to 6

Strength 40.

Effluents.

	Single contact beds.	Percolating filters of coarse material.	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	150 galls. (3 fillings) ...	200 galls. ...	200 galls. ...	30,000 to 40,000 galls. per acre per day (6 to 8 galls. per sq. yd.).
Ammoniacal nitrogen	0·5 ...	0·5 ...	0·25 ...	0·2
Nitric nitrogen	0·75 ...	1·0 ...	1·5 ...	0·5 to 1·0
Oxygen absorbed in 4 hours	1·0 ...	1·0 ...	0·5 ..	0·4
Suspended solids	1·0 ...	3·0 to 4·0 ...	1·5 ...	None.
	Fine material.			

Continuous flow settlement for 12 hours.

Settled Sewage.

Ammoniacal nitrogen	2·3
Oxygen absorbed in 4 hours	4·0
Suspended solids	7 to 8

Strength 45.

Effluents.

	Double contact beds.	Percolating filters of coarse material.	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	100 galls. (4 fillings) ...	150 galls. ...	150 galls. ...	30,000 gallons per acre per day (6 galls. per sq. yd.).
Ammoniacal nitrogen	0·5 ...	0·5 ...	0·25 ...	0·2
Nitric nitrogen	1·0 ...	1·0 ...	1·5 ...	0·5 to 1·0
Oxygen absorbed in 4 hours	1·0 ...	1·0 to 1·5 ...	0·5 ...	0·4
Suspended solids	1 to 2 ...	4·0 to 5·0 ...	2·0 ...	None.
	3 fillings for Primary beds; 5 fillings for Secondary beds. Rate of filtration could not be doubled in wet weather.			

Septic tanks. 24 hours' continuous flow.

Septic Tank Liquor.

Ammoniacal nitrogen	2·5
Oxygen absorbed in 4 hours	4·0
Suspended solids	7 to 8

Strength 45.

Effluents.

	Double contact beds.	Percolating filters of coarse material.	Percolating filters of fine material (shallow).	Good land (Filtration with little cropping).
Rate of filtration per cube yard per day.	100 galls. (4 fillings) ...	150 galls. ...	150 galls. ...	30,000 gallons per acre per day (6 galls. per sq. yd.).
Ammoniacal nitrogen	0·5 ...	0·5 ...	0·25 ...	0·2
Nitric nitrogen	1·0 ...	1·0 ...	1·5 ...	0·5 to 1·0
Oxygen absorbed in 4 hours	1·0 ...	1·0 to 1·5 ...	0·50 ..	·4
Suspended solids	1·0 to 2·0 ...	4·0 to 5·0 ...	2·0 ...	None.
	3 fillings for Primary beds; 5 fillings for Secondary beds. Rate of filtration could not be doubled in wet weather.			

NOTES.—(1.) The numbers given for "strength" of sewage represent *approximately* the parts by weights of oxygen required to oxidize 100,000 parts.

(2.) "Oxygen absorbed in 4 hours" means Oxygen absorbed in 4 hours at 27° C. (80° F.) from an eighth-normal solution of permanganate of potash (3·94 grms. per litre), rendered acid with dilute sulphuric acid.

(3.) All figures of analysis are stated in parts per 100,000.

(4.) By a "deep" filter we mean one of 5 to 6 feet and upwards in depth; by a "shallow" filter one which is below 5 feet in depth and usually about 3 feet. It would probably be inadvisable at the present time to build any sewage filter of a less depth than 2 feet 6 inches.

(5.) At first sight it may seem curious that the same figures of analysis should be given for the land effluents in this class. It has, however, to be remembered that the mechanical straining effect of land is such that all liquors derived from the same sewage must necessarily be brought more or less into line, and, further, that volume of sewage is a more important factor in land treatment than strength.

(6.) The figures of analysis for effluents refer to the effluents including their suspended solids.

Filters.

Single contact beds will, generally, only yield a good effluent where the sewage to be purified is weak, and then only after good preliminary treatment. For the purification of partially settled weak sewage and for well as also for partially settled sewage of average strength, if the case is one in which a good effluent is required, double contact is necessary, while, if a strong sewage has to be purified, triple contact is necessary unless the preliminary treatment is exceptionally good.

In nearly every case a greater rate of filtration can be adopted if the material is arranged in the form of a percolating filter than if it is used in contact beds. The rate of filtration per cube yard in the case of percolating filters may, generally, be double or nearly double that which is permissible in the case of contact beds.

As regards percolating filters, where the liquor to be treated is weak, and the preliminary treatment has effectively removed the greater part of the suspended matter, it is probably best, in most cases, to use fine material arranged in the form of shallow filters.

Where the sewage to be treated is strong, and especially if the preliminary treatment leaves a considerable quantity of suspended matter in the tank liquor, it is best to use deep filters of coarse material.

Where the liquor to be treated contains much suspended matter, it is usually advisable to construct percolating filters of coarse material, *whatever the strength of the original sewage.*

For sewages of about average strength, from which most of the suspended matter has been removed in the preliminary treatment, either coarse or fine material may be used.

It may be added that, with very well clarified weak sewage, filters with a top layer of very fine material, such as sand, can be made to give good results with a rate of filtration of 400 or even 500 gallons per cube yard per day. In this case, however, the materi l must be washed (*e.g.*, by upward flow of tank liquor) at short intervals of, say, a week.

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284. The three appended tables have been prepared to show the kind of results which may be expected by treatment, in various ways, of strong, medium, and weak sewages. The figures, in the majority of cases, are averages from a fair number of samples, and where they are not based on actual observations, they have been arrived at from general experience.

It has been assumed that the sewage does not contain trade waste or any other substance in sufficient quantity to inhibit the action of the micro-organisms, that the works are efficiently managed, and that the filtering material used in the filters has a rough and vesicular surface.

The rates of treatment per cube yard of filter, or per acre of land, which are given are for the dry weather flow, but except in the cases noted on the tables, they are rates which can be doubled during storm times.

The actual size of plant, or area of land, which would be required in any case would depend on the extra amount of sewage which, in the particular case, had to be treated on land or on filters in wet weather.

As we shall subsequently explain,* we think that local conditions should determine what this extra amount should be.

The question of comparative cost of land treatment and artificial treatment has been dealt with in an earlier section of this Report, and also considerations arising out of the risk of nuisance from the different methods of treatment.

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* *See* pp. 209 and 210.

TREATMENT OF STORM-WATER SEWAGE.

285. The proportion of rain-water from a drainage area which reaches the sewers and is conveyed to the outfall depends very largely on local circumstances, and consequently differs at different places.

Where, for example, the greater part of the drainage area consists of roofs and paved roads, the proportion of rain flowing off by the sewers will be greater than where the area chiefly consists of a more or less pervious soil.

Further, the amount of rain reaching the outfall will depend, to some extent, on whether the district is flat or hilly, the gradient of the main and tributory sewers, and what storm overflows are provided.

The system of sewerage will also make a considerable difference to the volume of liquid arriving at the outfall. Where a completely separate system of sewers for surface water exists, there will be only a small increase in volume due to rain ; with the partially separate system, there will be a considerable increase ; and with the combined system, a still greater increase.

286. At Hampton, which is provided with a separate system of sewers for surface water, we estimated the dry weather flow during the years 1902 and 1903 to be approximately 150,000 gallons per day, and the actual daily flow in all weathers to be about 165,000 gallons on the average—an increase due to rain of 10 per cent. only.

At Horfield, where the drainage area is sewered upon the partially separate system, but where there are no storm-overflows, gaugings over four months (April, May, June and July, 1905) showed the average daily flow to be approximately 62,350 gallons. As the dry weather flow was approximately 38,000 gallons per day, this represented an increase of 64 per cent. on the dry weather flow.

At Little Drayton, where the sewerage is on the combined system, and where there are two storm-overflows, one of which was temporarily dammed for the purposes of our observations, gaugings over three months (January, February and March, 1905) showed that the average daily flow was 15,350 gallons, or about 30 per cent. above the dry weather flow of 12,000 gallons.

At Rhyl, where the sewerage of the area is upon the combined system, and where there were no storm-overflows, gaugings made by Mr. Baldwin Latham for two entire years (1900–1901) gave the following figures. (Report* by Mr. Baldwin Latham to the Commission, June 29th, 1903, pp. 3 and 17) :—

Rainfall.	Number of days on which 0·01 inch or more rain fell.	Total flow in sewers.	Dry weather sewage flow, including subsoil water.	Water supply.	Rainfall flowing off (*i.e.*, increase in flow due to rain).	Rainfall and subsoil water.
Inches.		Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1900						
26·52	168	165,683,520	123,281,534	91,438,652	42,401,986	74,244,868
1901						
20·46	139	159,161,870	121,825,485	97,385,727	37,336,385	61,776,143

* Appendix V.

The increase of volume in this case, therefore, amounted to an average of 32·5 per cent. on the dry weather flow over the two years.

In his report, Mr. Baldwin Latham gives the following figures for Deal, which was also sewered on the combined system and had no storm-overflows:—

September, 1901, to February, 1903, inclusive.

Rainfall.	Number of days on which 0·01 inch or more rain fell.	Total flow in sewers.	Dry weather flow.	Rainfall flowing off.	Water supply to district.
Inches.		Gallons.	Gallons.	Gallons.	Gallons.
33·525	250	183,996,063	152,883,153	31,112,910	136,059,220

In this case, therefore, the increase was 20·35 per cent. on the dry weather flow.

At Rochdale, which is sewered upon the combined system, where the greater part of the area is paved or roofed, but where some thirteen storm-overflows exist, Mr. S. S. Platt, the Borough Surveyor, by gaugings extending over the year 1904, showed that the increase was roughly 52 per cent. of the mean dry weather flow.

At Oswestry, where the combined system is in use, but where the main storm-overflow is set rather low, Mr. G. W. Lacey, the Borough Surveyor, has found the increase to be about 21 per cent. of the mean dry weather flow. In this case a large quantity of subsoil water gains access to the sewers.

At Chorley, where the combined system is in use, where the main storm-overflow is set at about three times the mean dry weather flow, and where there are two local storm-overflows, the increase is about 45 per cent. In this case a small stream finds its way into the sewers.

In his report already mentioned, Mr. Baldwin Latham gives gaugings of the sewage flow at Croydon for the years 1880 to 1886 inclusive. The figures are summarised in Table 14, p. 28 of the report. From these figures, it will be seen that the increase of flow at that town due to rainfall was only 11·6 per cent. on the dry weather flow in the sewer, as calculated from the water supply. But it should be specially noted that in this case subsoil water is present in the sewers in the proportion of about 1·5 volumes to 1 of sewage, the consequence being that all variations of flow in the sewers are considerably levelled down.

Croydon is sewered upon the partially separate system, and there are no storm-overflows on the system.

287. While it is obvious from these few examples that the circumstances of different places vary considerably, the data available in regard to the effect of storms on the flow of sewage are exceedingly scanty.

In some few places records have been kept for a considerable period of the variation in flow in the outfall sewer and of the volume of sewage treated, but, so far as we are aware, there is little or no information available showing the volumes of liquid which have passed over storm overflows during the same period. It is, however, in some cases enough to do considerable damage to the river.

In the present state of knowledge, we consider that any regulations in regard to the amount of storm sewage to be treated and the method of treatment should be of a tentative character, and that, as regards storm overflows, each place must, to a great extent, be dealt with according to local circumstances. The general principle which should be followed is, we consider, that each local authority should so arrange its sewerage system as to prevent unpurified sewage from passing into the river or stream to an extent likely to cause nuisance.

288. As regards the effect of storms on the character of the sewage, the evidence which we have received, and also our own observations, show that, for the first hour or more, the effect of a storm is to increase the amount of organic matter in solution in the sewage as it arrives at the works, and also very largely to increase the suspended solids.

In our experience, the first flush of storm water contains a very large quantity of suspended matter washed out of the sewers, and is organically very impure. This flush, moreover, usually occurs at the time when the rainfall flowing off the area causes the maximum flow in the sewer, the consequence being that an ordinary storm-overflow on the sewers often has the effect of diverting to a water-course the worst part of the storm-water, while allowing the less foul storm sewage which arrives later to pass to the tanks or filters.

289. As a general rule, the difficulty of dealing with storm-water lies, not so much in the actual quantity flowing off an area as the result of rain, as in the rate at which it flows off. This is, of course, much more marked at some places than at others, the flow-off of rain-water being much more rapid when the greater part of the drainage area is more or less impervious, where the district is hilly, or where the sewers are laid upon a steep gradient. For instance:—

At Calverley—population 2,300—where the district is hilly, the main sewer steep, the sewerage system combined, and with rock immediately underlying the soil, as the result of a rainfall of 0·46″ falling in five showers on June 9th, 1902, the flow of sewage showed five sudden rises bringing the rates of flow up to 13, 32, 26, 29 and 30 times the mean dry weather flow. The total flow of sewage for the day, however, was only increased from the mean dry weather flow of 12,000 gallons to 43,700 gallons, or 3·64 times.

If a storm overflow had been set at Calverley to come into operation when the rate of flow was six times the mean dry weather flow, a large quantity of storm-water would have been discharged, untreated, on this day; whereas if a reserve empty tank, with a holding capacity of about 12,000 gallons, had been provided, and the overflow had been from this tank, the whole of the sewage and storm-water would have been treated; the beds receiving 3·64 times the normal quantity of sewage.

This is not an unusual occurrence at Calverley, and it has, moreover, been often observed there and at other places that the storm sewage is usually most foul when the storm flow is at its maximum rate.

On the other hand, if the district is flat, and especially if there is much leakage of subsoil water into the sewers, the flow of sewage will increase less rapidly as the result of rain, but continue swollen for some hours, or possibly some days. Halton, Oswestry, and Newton-le-Willows may be cited as illustrations.

290. In our opinion, the difficulties of dealing with the increase in flow, due to storms, can best be met by the provision of stand-by tanks to receive the storm sewage in excess of that which can be passed through the ordinary tanks. The main overflow at the works should be from the stand-by tanks, and not from the outfall sewer, so that no sewage may escape without some settlement.

The stand-by tanks should, of course, be kept empty as far as possible, so as to be at once available when a storm comes on.

We have not sufficient experience to enable us to suggest by what rules the capacity of the stand-by tanks should be determined, but we should think that tanks capable of holding a †quarter (six hours' flow) of the mean daily dry weather flow would usually be sufficient.

Local circumstances would, however, have to be considered in settling the capacity required for any particular place.

291. As illustrating the effect of stand-by tanks of the capacity suggested, we may give some figures taken from the report of Mr. Baldwin Latham, to which we have already referred.

At Friern Barnet sewage works, during nineteen wet days (average rainfall at the sewage works, 0·281″ per day), in August, September and October, 1887, instead of a total dry weather flow of sewage of 232,009 cubic feet, 515,793 cubic feet were found to arrive, 283,784 cubic feet being therefore due to rain. Of the total (515,793 cubic feet), 125,679 cubic feet, or 24·37 per cent., arrived at a rate in excess of three times the mean dry weather flow; 89,558 cubic feet, or 17·36 per cent., in excess of four times the mean dry weather flow; 67,412 cubic feet, or 13·07 per cent., in excess of five times the mean dry weather flow, and 50,015 cubic feet, or 9·7 per cent., in excess of six times the mean dry weather flow.

Assuming that all sewage up to three times the mean dry weather flow had been taken through the ordinary precipitation tanks, and that all flows in excess of this were directed into stand-by tanks of capacity 3,050 cubic feet (the dry weather flow at Friern Barnet was 12,211 cubic feet per day), then, out of a total of 515,793 cubic feet, 390,114 cubic feet (75·6 per cent.) would have been filtered in the ordinary way, and 125,679 cubic feet, or 24·37 per cent., would have received, before discharge into the water-course, the settlement shown in the following table :—

† Stand-by tanks are, we believe, giving excellent results at Colne, Lancashire, and also at Chorley. We understand the stand-by capacity at Colne is equal to about one-half the daily dry weather flow, and at Chorley to about one-third of the dry weather flow.

Date.	Number of hours the flow exceeded 3 times the mean dry weather flow (which was 12,211 cubic feet per day).	Volume of sewage in excess of 3 times the mean dry weather flow.	Settlement given in stand-by tanks.
1887.		Cubic feet.	
Aug. 16	5 hours	9,588	1 to 6 hours' continuous flow settlement after filling.
„ 17	1 hour	634	Quiescent settlement.
„ 20	1 hour	118	Quiescent settlement.
„ 26	3 hours	3,485	Mostly quiescent settlement.
„ 28	2 hours	1,243	Quiescent settlement.
„ 29	1 hour	1,492	Quiescent settlement.
„ 30	10 hours	16,620	1 to 6 hours' continuous flow settlement.
„ 31	8 hours	32,554	1 to 6 hours' continuous flow settlement.
Sept. 1	12 hours	11,909	1 to 6 hours' continuous flow settlement.
„ 2	3 hours	1,150	Quiescent settlement.
„ 3	6 hours	4,583	Quiescent settlement
„ 4	1 hour	118	Quiescent settlement.
„ 6	3 hours	6,341	1 to 6 hours' continuous flow settlement.
„ 7	9 hours	5,238	1 to 6 hours' continuous flow settlement.
„ 16	4 hours	5,246	1 to 6 hours' continuous flow settlement.
„ 17	9 hours	17,431	1 to 6 hours' continuous flow settlement
„ 26	3 hours	2,246	Quiescent settlement.
„ 30	3 hours	1,175	Quiescent settlement.
Oct. 10	5 hours	4,506	1 to 6 hours' continuous flow settlement.

The results obtained by Mr. Baldwin Latham at Croydon throughout the years 1880 to 1886 show that in a total number of 139 days upon which heavy rain fell (average rainfall per day 0·488″), out of a total of 73,768,896 cubic feet of sewage and rain-water flowing in the sewer, 12,201,773 cubic feet (or 16·2 per cent.) arrived at a rate in excess of three times the mean dry weather flow.

Taking the dry weather flow at Croydon to be 321,000 cubic feet, stand-by tanks of the capacity suggested would, in this case, have held 80,000 cubic feet, and, if the whole of the sewage and storm-water up to three times the dry weather flow had been passed through the ordinary tanks and plant, then 16·2 per cent. (12,201,773 cubic feet) of the total flow would have been sent into the stand-by tanks. Of the 139 wet days during the period stated, the total flow in excess of three times the dry weather flow only exceeded 80,000 cubic feet, or the assumed capacity of the stand-by tanks, on fifty-two days. In this case, of the total flow of 12,201,773 cubic feet, in excess of three times the dry weather flow, 7,696,935 cubic feet would have received quiescent settlement in the stand-by tanks and 4,504,838 cubic feet from one to six hours' continuous flow settlement, before discharge into the water course.

Mr. Latham's gaugings of the South Norwood sewage flow show that on fourteen wet days between January 13th and August 11th, 1866 (average rainfall per day 0·35″), out of a total flow of sewage and storm-water of 1,617,594 cubic feet, of which not less than 1,268,217 cubic feet were due to rain, 881,453 cubic feet (or 54·49 per cent.) arrived at a rate in excess of three times the dry weather flow.

In this case, the provision of stand-by tanks of the capacity suggested (six hours' flow) would have given quiescent settlement to 59,083 cubic feet out of the total flow of 881,453 cubic feet in excess of three times the dry weather flow, and one to six hours' continuous flow settlement to 822,370 cubic feet before discharge into the water-course.

It is to be observed from Mr. Baldwin Latham's report "that there were no storm-overflows in connection with the South Norwood sewers at the time the gaugings were made, and that, the district being of a more or less impermeable character, the volume of rain entering the sewers is very considerable, having regard to the extent of the district and the population draining to the sewers."

We are greatly indebted to Mr. Baldwin Latham for the Report which he kindly made to us on the subject of the increase in the flow of sewers caused by storms. This Report is published in Appendix V.

Storm Water Filters.

292. Speaking generally, we are not in favour of special storm-water filters, for although, if well constructed and scientifically managed (*e.g.*, as at Manchester), they can be made to give good results, our experience has led us to the conclusion that—as generally constructed and used—they do not effect a purification in proportion to their cost.

If storm-water filters are not regularly used, their oxidising efficiency may, in times of dry weather, become impaired. If, therefore, they are to be used in dry weather, in order that they may be kept mature, it appears to us that they should be as well and as carefully constructed as the ordinary filters. It seems also false economy to have some part of the filtering area out of use for any length of time when the additional area, if used, would be of advantage in giving regular periods of rest to sections of the normal filtering area.

Amount to be filtered.

293. We think it may be taken that it is practicable to filter three times the mean dry weather flow, and while there are few or no data to show that this is the right amount for which filtration is required, we doubt whether, as a general rule, the filtration of any larger amount will be found to be necessary to prevent nuisance.

Assuming, that three times the dry weather flow had to be filtered, we consider that it would only be necessary to provide at a works $1\frac{1}{2}$ times the area of filter which would be necessary if only the dry weather flow had to be treated; this area would, in our opinion, allow of the filtration of three times the mean dry weather flow, as the filters can be worked at an increased rate during storms.

Recommendation.

(a) *Overflows on Branch Sewers.*

294. It is probably impracticable to dispense altogether with storm overflows on branch sewers, but in our opinion these should be used sparingly, and should usually be set so as not to come into operation until the flow in the branch sewer is several times the maximum normal dry weather flow in the sewer.

No general rule can be laid down as to the increase in flow which should occur in the branch sewers before sewage is allowed to pass away by the overflow untreated. The Rivers Board, or in districts where there is no Rivers Board, the County Council, should have power to require the local authority to alter any storm overflows which, in their opinion, permit of an excessive amount of unpurified sewage to flow over them. The local authority should have the right to appeal to the Central Authority in any case in which they consider that the requirement of the Rivers Board is unreasonable or impracticable of fulfilment.

The general principle should be to prevent such an amount of unpurified sewage from passing over the overflow as would cause nuisance.

(b) *Treatment of Storm Water Sewage at the Works.*

295. The usual requirements of the Local Government Board in regard to the treatment of storm sewage are that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. These requirements should, we think, be modified: they are, in our opinion, not sufficiently elastic; and, moreover, experience has shown that special storm filters, which are kept as stand-by filters, are not efficient. We find that the injury done to rivers by the discharge into them of large volumes of storm sewage chiefly arises from the excessive amount of suspended solids which such sewage contains, and that these solids can be very rapidly removed by settlement. We therefore recommend, as a general rule—

(1) That special stand-by tanks (two or more), should be provided at the works and kept empty for the purpose of receiving the excess of storm water which cannot properly be passed through the ordinary tanks. As regards the amount which may be properly passed through the ordinary tanks, our experience shows that in storm times the rate of flow through these tanks may usually be increased up to about three times the normal dry weather rate without serious disadvantage;

(2) That any overflow at the works should only be made from these special tanks, and that this overflow should be arranged so that it will not come into operation until the tanks are full;

(3) That no special storm filters should be provided, but that the ordinary filters should be enlarged to the extent necessary to provide for the filtration of the whole of the sewage, which, according to the circumstances of the particular place, requires treatment by filters.

(4) As regards the overflow from the outfall sewer to the stand-by tanks, the size of the stand-by tanks, the amount of storm sewage which should be filtered, and the arrangements generally for dealing with storm sewage at the outfall works, the Rivers Board, or the County Council in areas in which no Rivers Boards have been established, should have similar power to that which we have proposed in regard to overflows on branch sewers, and the Local Authority should have a similar right of appeal to the Central Authority.

SEPARATE AND COMBINED SYSTEMS OF SEWERS.

296. In recent years there has been a tendency to favour the adoption of separate sewers to carry what is called surface water, and some local authorities have obtained, by means of local acts, special powers enabling them to call upon frontagers in private streets to lay down two sewers instead of one.

In the Public Health Bill of last session (1907) a clause, dealing with this subject, was originally included, but it was omitted during the passage of the Bill through Parliament.

In our opinion the cases in which the provision of a separate system can properly be justified are rare, and it appears to us that the relative merits of the separate and combined systems have not always been sufficiently considered.

It is obvious that the provision of two systems of sewers and two sets of house drains would very largely increase the initial outlay on drainage works, the exact amount of the increase depending on local circumstances.

It seems generally to have been assumed by advocates of the separate system that the liquid brought down by surface water sewers is sufficiently pure to need no purification, and further, that by excluding this water from the ordinary sewers a much smaller area of land or filters, as the case may be, will suffice for the purification of the sewage.

Neither of these assumptions is altogether justified.

297. As regards the quality of the liquids which are discharged from surface-water sewers, we may refer to the following analyses which we have made :—

Chemical Analyses.

	Rugby.	Aldershot Camp.		South Norwood.			
No. of Sample.	231	311	314	174	179	182	187A
	Street washings taken from a surface water drain. Street very clean from heavy showers.	Street washings from surface ditch.	Street washings.	Street water. Incubated before analysis.	Surface street water. Incubated before analysis.	Street washings after running 2 hours.	Street water after 0·04″ rain.
	Monday, March 4th, 1901, 10 a.m.	Tuesday, July 2nd, 1901, 12.45 noon.	Wednesday July 3rd, 1901, 11.45 a.m.	Wednesday November 14th, 1900, 2.15 p.m.	Wednesday November 21st, 1900, 1.0 p.m.	Wednesday November 28th, 1900, 12.45 noon.	Saturday, December 1st, 1900, 11.15 a.m.
Ammoniacal Nitrogen	0·09	0·49	1·70	0·19	1·25	0·47	0·52
Albuminoid Nitrogen	0·10	0·49	0·34	0·06	0·14	0·42	0·08
Total Organic Nitrogen	0·23	1·05	0·64	—	—	0·65	—
Nitrous Nitrogen	0·01	trace.	0·0	0·24	—	trace.	0·10
Nitric Nitrogen	0·05	0·12	0·02			0·42	
Oxygen absorbed *at once*	0·66	2·76	0·81	0·39	—	2·76	0·23
Oxygen absorbed *in* 4 *hours*	1·83	8·93	3·46	—	—	9·79	—
Incubator test	Sweet.	Black Sulphides.	Black Sulphides.	No smell.	Putrid black Sulphides.	Strongly putrid.	Clean.
Suspended solids by Centrifuge (vols.)	91·0	Too gritty.	65	—	—	—	—
	Not much traffic on this street. The sample was brown and turbid, with a large amount of gritty sediment.	Turbid and brown, but the liquid had only a slight brown tinge when filtered. Much sand and also brownish suspended matter. Clean smell.	Turbidand brown. Considerable suspended matter with grit at bottom of bottle. Very slight putrid smell.	Liquid had a slight brown tinge. Much sand. Very pure (chemically).	No smell.	Very turbid. Filtered liquid brown but fairly clear. Much grit. No smell.	Dark coloured flocculent sediment.

Bacteriological Analyses.

Description of Sample.	Total number of Bacteria per c.c.		Number of B. Coli (or closely allied forms per c.c.).	Number of Spores of B. Enteritidis sporogenes per c.c.
	Gelatine at 20°C.	Agar at 37°C.		
96A. Rugby. Street water from separate system. June 20/00.*	15,900,000	94,000	10,000 (Indol + ·0001 c.c.) + ·01, – ·001 c.c. "gas" in gelatine shake culture.	+ ·1, – ·01 c.c. At least 10 but less than 100.
231. Rugby. Street "Washings." March 4/01.§	930,000	12,400	1,000 (Indol + ·001 c.c.) Negative result with ·1 c.c. "gas" in gelatine shake culture. + ·01, – ·001 c.c. Neutral red broth test. + ·01, – ·001 c.c. Litmus milk test.	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
311. Aldershot Camp. Street "Washings." July 2/01.	7,500,000	640,000	+ ·0001, – ·00001 c.c. Neutral red broth test. + ·001, – ·0001 c.c. Litmus milk test. + ·001, – ·0001 c.c. "gas" in gelatine shake cultures.	+ ·1, – ·01 c.c. At least 10 but less than 100.
314. Aldershot Camp. Street "Washings." July 3/01.	22,800,000	900,000	+ ·00001 c.c. Neutral red broth test. + ·0001, – ·00001 c.c. Litmus milk test. + ·001, – ·0001 c.c. "gas" in gelatine shake cultures.	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
174. S. Norwood. Brook (represents street "Washings"). 14/11/00.	1,470,000	88,000	At least 10 (Indol + ·1 c.c.). + ·1, – ·01 c.c. "gas" in gelatine shake cultures.	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
179. S. Norwood. Surface water from streets. 21/11/00.	3,840,000	293 000	10,000 not 100,000 (Indol + ·00001 c.c.). + ·01 c.c. "gas" in gelatine shake cultures.	+ ·1, – ·01 c.c. At least 10 but less than 100.
182. S. Norwood. Street water after running 2 hours. 28/11/00.	13,700,000	154,000	10,000 (Indol + ·0001 c.c.).	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
188B. S. Norwood. Street "Washings" after running 4 hours. 1/12/00.†	9,900,000	380,000	1,000 (Indol + ·001 c.c.) + ·1, – ·01 c.c. "gas" in gelatine shake cultures.	+ ·01, – ·001 c.c. At least 100 but less than 1,000.

* Two guinea-pigs (a and b) were subcutaneously inoculated with 1 c.c. (a) and 2 c.c. (b) of sample 96A (street washings). Both showed a strong local reaction; (a) guinea-pig recovered, but (b) guinea-pig suffered from ulceration of the abdominal wall and died on the fourth day.

† Two guinea-pigs (a, b) were subcutaneously inoculated with 1 c.c. (a) and 2 c.c. (b) of sample 188B; (a) guinea-pig developed a big swelling at the site of the inoculation, but eventually recovered completely; (b) guinea-pig died on the second day.

§ A guinea-pig was subcutaneously inoculated with 4 c.c. of sample 231 (street washings). It died on the second day, doubtless from the effects of the injection.

The chemical analyses of these samples may be shortly summarised as follows :—

No. 231, street "washings" taken from a surface-water drain at Rugby on March 4th, 1901, at a time when the street was very clean after heavy showers, was turbid and brown with a large amount of gritty sediment, but comparatively pure as regards organic matter; it withstood incubation.

No. 311, street "washings" from a surface-water ditch at Aldershot, was drawn on the 2nd July, 1901, after two days' heavy rainfall; at the time of drawing, the water in this ditch was flowing at about the rate of ten million gallons per 24 hours. The above sample was brown and turbid (though it had only a slight brown tinge when filtered), and it contained a great deal of sand and also brownish suspended matter. The analyses gave the high figure of 0·49 parts Albuminoid Nitrogen, 1·05 Total Organic Nitrogen, and 8·93 "Oxygen absorbed" in four hours. Though this had a clean smell when analysed, it became black and putrid on incubation.

No. 314, street "washings" and roof water from Aldershot Camp, drawn July 3rd, 1901, after three days' rain, was muddy from a considerable quantity of suspended solids with grit in addition. Though the aggregate organic matter was less than in sample No. 311 (the figures being 0·34 Albuminoid Nitrogen, 0·64 Total Organic Nitrogen, and 3·46 "Oxygen absorbed"), it was smelling slightly when analysed and became black and putrid on incubation.

No. 174, drawn November 14th, 1900, was a sample of surface water from streets and front roofs drawn at South Norwood during sharp showers, the weather having been showery on the day previous. It contained a good deal of sand, but was comparatively pure as regards organic matter and kept good upon incubation.

No. 179, drawn November 21st, 1900, was another sample of surface water from the South Norwood streets, after moderate showers, the streets having been previously washed fairly clean by rain. This did not contain much sediment, but was organically more impure than the preceding sample; it had no smell when received, but became putrid upon incubation.

No. 182 was drawn on November 28th, 1900, at South Norwood, after the surface drain had been running for three hours. It was very turbid and brown and contained much grit. Organically, it might be classed as a dilute sewage.

No. 187a, South Norwood street water, drawn December 1st, 1900, after a slight rainfall, was comparatively pure as regards organic matter. Though it showed a good deal of flocculent sediment, it kept sweet upon incubation.

Three out of these seven samples were therefore non-putrescible; but the other four were undoubtedly polluting liquids.

Bacteriologically, all the samples may be classed as bad.

Although the above samples were few in number, they show (1) that even when a street water is comparatively pure organically, it requires settlement for grit (Nos. 174 and 231); and (2) that even after long-continued rain, street surface waters may be very impure (Nos. 182, 311 and 314).

Valentine, 22407. Wilkinson, 22603. Wike, 23515. Reid, 20730–1.

298. The witnesses who have given evidence on this question have agreed that the first flush of water from a surface-water system during a storm is of such a foul nature that it ought to be purified, if practicable, especially if the system brings water from paved open spaces such as markets, squares, etc.

Messrs. G. H. Pickles and Raymond Ross gave the following analysis of a typical sample of surface water from a surface-water drain at Burnley, taken during the early period of a storm :—

	Parts per 100,000.
Free Ammonia	·8
Albuminoid Ammonia	·2
Chlorine	4·0
Oxygen absorbed	5·3
Total solids	71·2
Suspended matter	44·0

They stated, also, that this sample contained about 800,000 bacteria per c.c. as shown by gelatine plate cultivation at 23°C.

Mr. Bolton, in his evidence relating to Heywood, gives the following analysis of a sample of road water, taken in the principal streets during the first rushes of storm surface water :— 21096.

	Parts per 100,000.
Ammoniacal Nitrogen	1·11
Albuminoid Nitrogen	·49
Oxygen absorbed in 3 minutes	12·5
Oxygen absorbed in 4 hours	19·9
Chlorine	8·7
Solids in suspension	84 { vol. 25 / non vol. 59
Solids in solution	73 { vol. 22 / non vol. 51
Total solids	157

299. Experience also shews that with two sets of drains to each house there is danger of the sewage drain being connected with the surface-water sewer, and in densely populated areas, slops and other filthy liquids are often emptied into street gullies, and pass directly into the surface-water sewer.

There can be no doubt, therefore, that the liquid brought down by surface-water sewers is frequently of a polluting nature, and that, in many cases, it might be necessary to provide for its treatment.

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300. As to the other assumption, that by keeping surface water out of the sewers the area of filters or land necessary for purification may be materially reduced, we may refer to the experiments which we carried out at Accrington, in regard to the filtration of diluted and undiluted septic tank liquor (see pages 16 and 110 *et seq.*).

These experiments shewed that, within ordinary limits of concentration and volumes treated, the amount and nature of the organic impurity present mainly determine, in practice, the ease or difficulty of purification; in other words, that, within limits, mere dilution does not affect the size of the filtering plant which is necessary. Of course, if the dilution is so great as to cause water-logging of the filters, their purifying power would be seriously diminished, and this statement would not hold good.

We may also observe that the flushing of sewers by rain water, which occurs with the combined system, is in itself useful, and that there is some evidence to show that filters work better when storm sewage, from which the solids have been settled, is occasionally passed through them.

24260, Fowler. 22745, Watson. 24955, Wilkinson.

301. As regards the cases in which the adoption of a separate system for surface water may be allowed, we may refer to the evidence of Dr. Fowler, Mr. Watson, and Mr. Wilkinson. These gentlemen have had considerable experience, and they expressed the view that in large towns the separate system is impracticable, that in urban districts a combined system is justified on sanitary and economical grounds, and that only in villages, country districts, and suburban areas, where there is little traffic and where the surface water will not be very foul, may the separate system sometimes be adopted with advantage.

With these views we generally concur, and we think it would be unwise to confer on all local authorities power to enforce the adoption of the separate system of sewerage, and the provision of two sets of drains in every house.

In our opinion this power should not be conferred on any local authority until the local circumstances have been carefully considered by some independent tribunal.

Recommendation.

302. We recommend that in any case in which a local authority wishes to adopt the separate system of drainage for the whole or any part of their district, they should be required to apply to the Central Authority, and that the Central Authority should be empowered to confer on the local authority, by order, such powers as may be deemed necessary.

As regards the powers which may be necessary, we may observe that the provisions which are generally contained in local Acts in regard to this matter seem to be defective. If separate sewers are provided, the local authority should have a clear power to enforce the provision of separate drains, but the local Acts to which our attention has been drawn do not modify the powers of the local authority under the general law in regard to bye-laws as to the drainage of houses.

Moreover, the powers of the local authority in this connection should not necessarily be limited to new streets and new houses.

As a general rule, the expense of altering existing drains should fall on the local authority, and there may be some instances in which it would be equitable that they should bear some portion of the additional cost even in the case of drains being constructed for the first time.

The Central Authority should therefore have power to include in their Order such provisions for the allocation of the cost as they consider equitable, having regard to the local circumstances.

PART VI.—STANDARDS FOR SEWAGE EFFLUENTS.

303. A number of chemists and others were kind enough to furnish us with their views on the question of standards, in response to a circular letter which we issued in May, 1903. This letter and the replies are printed in Appendix VII.

We have also examined several witnesses on this subject, and have ourselves made some experimental investigations.

The harm caused by allowing unpurified, or imperfectly purified, sewage to flow into rivers and streams may be placed under one or more of the following headings:—The de-aeration of the water of the river, and consequent injury to fish; the putrefaction of organic matter in the river to such an extent as to cause nuisance; the production of sewage fungus and other objectionable growths; the deposition of suspended matter, and its accumulation in the river bed or behind weirs; the discharge into the river of substances, in solution or suspension, which are poisonous to fish or to live stock drinking from the stream; the discoloration of the river; and the discharge into the river of micro-organisms of intestinal derivation, some of which are of a kind liable, under certain circumstances, to give rise to disease.

304. We observe that previous Commissions have reported that, of all the processes which were proposed for the purification of sewage, or of water polluted by excrementitious matter, there is not one which is sufficiently effective to warrant the use, for dietetic purposes, of water which has been so contaminated, and the 1868 Commission stated that, in their opinion, "rivers which had received sewage, even if that sewage had been purified before its discharge, were not safe sources of potable water." We, therefore, conclude that the framers of the Rivers Pollution Prevention Act, 1876, did not contemplate that local authorities should be required so to deal with their sewage that the rivers into which the purified sewage flowed might be regarded as safe sources of water supply, in cases in which the water was not to be filtered before distribution.

305. In our opinion much the same position must be taken up to-day. Although the methods available for the purification of sewage are more numerous than when the 1868 Commission reported, our examination of a very large number of effluents from sewage farms, and from artificial filters of various kinds, shows that, although such effluents may be very good as judged by chemical and physical tests, they are generally liable to contain large numbers of micro-organisms of intestinal derivation, and that if such organisms are to be destroyed, or eliminated, the effluents must be subjected to some treatment additional to that which is ordinarily employed.

We have carried out some experiments for the purpose of ascertaining the practicability of certain of the methods which have been suggested for the removal or destruction of these micro-organisms. These experiments, which are described in Dr. Houston's Report, Appendix IV., have shown that, while it would be practicable to render sewage effluents fairly pure, bacteriologically, the cost of the necessary additional treatment would be serious.

306. Moreover, a false sense of security would be obtained by the adoption of such further treatment unless, at the same time, storm overflows on sewers were abolished.

In the great majority of towns, sewers are provided with storm overflows, by which, in times of storm, large quantities of sewage are discharged into the river or stream untreated. Such discharges, we find, are frequently more impure, bacteriologically, than the normal crude sewage.

In the opinion of some engineering witnesses whom we have called before us, it would generally be impracticable to dispense with storm overflows, but assuming, as an engineering possibility, that they could generally be dispensed with, it is quite clear that the necessary enlargement of the sewers would involve a very large outlay. In some towns, if there were no storm overflows, the effect of a storm would be to cause the flow in the sewers to be very many times the normal rate for a short period.

307. By constructing a separate system of sewers for storm water the effect of storms on the other sewers would no doubt be greatly lessened, but if bacterial purity is to be required in the case of all discharges from sewers, it would be necessary to provide a second plant for the treatment of the liquids flowing in the storm water sewers, as these liquids are often exceedingly impure.

The amount of liquid which would be brought down by such separate sewers would vary, according to local conditions, but during the course of a year it would probably be at least half as much as the volume carried by the other set of sewers.

308. In our opinion, the cost of reconstructing the sewers so as to allow of the abolition of storm overflows, together with the cost of providing and maintaining purification plant which could be relied on at all times to render the total refuse waters of a town both chemically and bacteriologically pure, would in most cases be practically prohibitive; and further, even if this additional burden were placed on local authorities, the water of rivers would generally still require to be treated before it could be safely distributed for drinking purposes.

309. We are satisfied that rivers generally, those traversing agricultural as well as those draining manufacturing or urban areas, are necessarily exposed to other pollutions besides sewage, and it appears to us, therefore, that any authority taking water from such rivers for the purpose of water supply must be held to be aware of the risks to which the water is exposed, and that it should be regarded as part of the duty of that authority, systematically and thoroughly, to purify the water before distributing it to their customers.

310. Apart from the question of drinking waters, we find no evidence to show that the mere presence of organisms of a noxious character in a river constitutes a danger to public health or destroys the amenities of the river. Generally speaking, therefore, we do not consider that in the present state of knowledge, we should be justified in recommending that it should be the duty of a local authority to treat its sewage so that it should be bacteriologically pure.

311. The evidence adduced before us and the results of our own investigations show that the extent to which the purification of a sewage need be carried in order that none of the other injuries mentioned in paragraph 303 shall be done to the river into which it is discharged varies with the particular circumstances of the town and river concerned.

The statute law, however, recognises no graduated standards of purity for sewage effluents.

Under the Rivers Pollution Prevention Act, 1876, in the case of sewage entering non-tidal waters, the duty is imposed on the local authority of adopting the best practical and available means to render the sewage harmless before it enters the river, and no local circumstances may be taken into account. The effluent by itself is alone to be considered.

312. We fully realise that from the point of view of administration it is simpler to regard the effluent alone, and also that it has not been usual for County Councils, Rivers Boards, or others, to press the provisions of the Act of 1876 unduly. Our terms of reference require us, however, to have regard to the "*economical* and efficient" discharge of the duties of local authorities, and in view of the importance of not requiring a local authority to incur any further expenditure on sewage disposal than the circumstances of its area require, we feel strongly that the law should be altered so as to allow local circumstances to be taken into account.

Suspended Solids in Effluents.

313. One point in regard to which we think that strict regulations will usually be found necessary is the reduction of the suspended solids of an effluent to a low figure, before that effluent is allowed to escape into a watercourse. As is well known, these suspended

solids are always—or practically always—putrescible. Indeed, we cannot recall any instance in our own experience in which such solids, when examined apart from the liquid portion of the effluent, were non-putrescible.

Our observations show that the volatile matter of the suspended solids in effluents from artificial filtration may be taken, on a rough average, as constituting about two-thirds of the whole, the remaining one-third being mineral matter. Although it is not strictly correct to say that this "volatile" matter is all organic, we think that it may be considered so for practical purposes.

A description, by Messrs. O'Shaughnessy and Kinnersley, of the suspended solids washed out in the effluent from one of the Birmingham percolating filters is to be found in the *Journal of the Society of Chemical Industry* for 1906. They found them to consist of a very complex mixture of structureless matter, dead organisms undergoing disintegration, zooglea, mineral matter, etc.

A large number of specific instances are given, in the *reports on the various sewage works which have been under observation for the Commission, of the rates at which such solids take up dissolved oxygen from water.

The results show that the suspended solids from biological sewage filters, whether contact beds or percolating filters, are in themselves putrescible, and that they are capable of taking up oxygen from water comparatively rapidly. So long as such solids are kept moving in oxygenated water, or in water containing nitrate in solution, they will not give rise to nuisance from smell, but if allowed to accumulate in the sluggish reaches of a stream, they will ultimately form black and putrid mud, which will draw upon the oxygen in the supernatant water ; if present in very large quantity, they will, in those circumstances, give rise to objectionable conditions.

314. Our own experience, and also the evidence which we have received, leads us to attach much importance to the prevention of a large amount of suspended solids being discharged into most rivers and streams, and our observations show that it is quite practicable to produce effluents fairly free from suspended solids.

The following places, among others, where various systems of treatment are followed, may be cited as giving a general effluent containing at most 3 parts of suspended matter per 100,000 :—

Birmingham.	Friern Barnet.	Royton.
Burnley.	Guildford.	Salford.
Carshalton.	Hampton.	Salisbury.
Caterham.	Hendon.	Staines.
Chesterfield.	Heywood.	St. Albans.
Chorley.	Kingston.	Shipley.
Clifton.	Newcastle-under-Lyme.	Wednesbury.
Darwen.	Oswestry.	Withington.
Dorking.	Prestolee.	Withnell.
Exeter	Radcliffe.	

As a general rule, we consider that the harm due to suspended solids would not be serious, if the effluents contained not more than 3 parts of suspended solids† per 100,000, and it is shown by experience that this would not be an unreasonable figure to demand in the majority of cases. There are, of course, cases where a larger quantity of solids might be safely allowed in an effluent, while in some others even 3 parts might be too much.

Other Qualities of Effluents.

315. We shall discuss in the next section of this report various tests for sewage effluents, but we may at once state that we doubt whether the figures obtained in the laboratory have, in the past, been sufficiently considered in connection with observed conditions of the stream to justify positive inferences being drawn from such figures as to the effect of effluents on streams.

* See Appendix III. † This is equivalent, as a rule, to about 2 parts of organic matter in suspension.

In connection with an investigation which we are making in regard to the disposal of distillery waste liquids, we have constructed a number of artificial streams. We find that effluents which are derived from strong original liquids may often contain large amounts of organic matter in solution, and yet not take up dissolved oxygen rapidly from water, or cause injury to streams into which they are discharged. If these observations had not been made such effluents, judged by the empirical tests in common use, might have been regarded as polluting liquids.

These observations, together with other experiments and the work done by others, show that the effect of an effluent on a stream does not generally depend on the absolute amount of organic matter contained in it, but rather on the nature and condition of that organic matter, and that the important thing to ascertain in examining an effluent, is the extent to which the original organic matter has undergone fermentation.

We are extending this method of observation to a variety of streams and effluents, and in our final report we hope to be able to indicate, by reference to figures obtained in the laboratory, a range of standards of varying degrees of stringency.

Recommendation.

316. We recommend that the Central Authority should determine the nature of the tests which are to be applied for the purpose of standards, and that it should be made the duty of the Rivers Board, or of the County Council, in areas not under the jurisdiction of a Rivers Board, to determine from time to time, subject to appeal to the Central Authority, what standards should be adopted.

317. In the first instance it would be convenient that the Central Authority should prescribe one standard for all non-tidal waters, in place of the existing statutory provisions. It would then rest with the Rivers Board or County Council to fix, subject to appeal to the Central Authority, a higher or lower standard, in any case in which they were of opinion that the circumstances required or justified a different standard.

318. We further recommend that no action should be allowed to be brought in respect of damage alleged to be due to the discharge of an effluent which complies with the standard fixed for the water into which it is discharged, but that in such cases complaint should be made to the Central Authority, and, if a *prima facie* case is made out, that Authority should ascertain whether the complaint is well founded and should be empowered to fix a different standard if the circumstances are shown to require it.

In cases where it is alleged that the effluent does not comply with the statutory standard, and that damage is caused by the discharge of such effluent, action should be brought in the ordinary courts.

But any questions arising as to whether the effluent complies with the statutory standard or as to whether the damage has been caused by the discharge of the effluent in respect of which complaint is made, should be referred by the Court to the Central Authority for determination. The costs of such determination should be borne by the parties to the action in such proportions as the Court may determine.

319. Power should be conferred on the Central Authority to suspend from time to time the operation of any standard, to allow time for the construction of works, or for any other reason which, in their opinion, justified such suspension.

TESTS FOR SEWAGE EFFLUENTS IN RELATION TO STANDARDS.

320. The experiments which we have already made show that the mere estimation of the amount of organic matter in an effluent does not, by itself, afford a sufficiently reliable index as to the effect which that effluent will have on any stream into which it may be discharged.

Effluents which are derived from strong sewages may contain comparatively large amounts of organic matters, and yet not take up oxygen rapidly from water or cause any serious growth of sewage fungi in streams, while effluents derived from weak sewages, although containing smaller amounts of organic matters, may take up oxygen comparatively rapidly and foul a stream into which they are discharged.

The primary object of applying tests to a sewage effluent should be to ascertain whether the effluent may be discharged into a stream without giving rise to effects such as these, and we are extending our observations on streams with a view to ascertaining the value of various tests from this point of view.

Until these observations are completed we do not propose to report finally on the question of tests and standards. We can, however, at once state that any figures of analysis, unless they bear a direct relation to the state of the effluent as regards fermentative change, may be misleading.

321. According to our present knowledge, an effluent can best be judged by ascertaining, first, the amount of suspended solids which it contains, and, second, the rate at which the effluent, after the removal of the suspended solids, takes up oxygen from water.

In applying this test it is important that the suspended solids should be removed, and estimated separately.

Small variations in the amount of suspended solids in effluents may seriously affect the rate at which the effluents take up oxygen, and unless these solids are first removed, the dissolved oxygen absorption test might give a misleading figure as to the character of the effluent.

322. For the guidance of local authorities we may provisionally state that an effluent would generally be satisfactory if it complied with the following conditions :—

(1) That it should not contain more than 3 parts per 100,000 of suspended matter ; and

(2) That, after being filtered through filter paper, it should not absorb more than :

(*a*) 0·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 24 hours ;

(*b*) 1·0 part by weight per 100,000 of dissolved or atmospheric oxygen in 48 hours ; or

(*c*) 1·5 parts by weight per 100,000 of dissolved or atmospheric oxygen in 5 days.

At many sewage works which we have had under observation effluents of this class are uniformly produced.

As regards the carrying out of the dissolved oxygen test, or aeration test as it is sometimes called, we may refer to page 15 of this Report, which deals with the test in relation to sewage, and also to pages 96 and 438 of Appendix VI.

Growths in Streams.

323. The question of growths in streams is one of some importance and difficulty.

Even the best effluents contain a certain amount of plant food in solution and therefore tend to promote vegetable growths. In the case of a stream receiving well purified and nitrated effluents, these growths are green. If, however, green growths form in quan-

tity, and become detached and washed down into stagnant pools, they must ultimately undergo decomposition and may possibly give rise to nuisance.

This aspect of the question is being further studied ; but we may remark that it does not seem practicable to purify sewage thoroughly without the production of nitrates which remain in the effluent, and tend to promote growths.

In the case of a stream receiving imperfectly purified effluents, grey growths (leptomitus, sphaerotilus, etc.) may be fostered. These not only give a stream an unpleasant appearance, and tend to choke its bed, but when washed down and allowed to accumulate, may become very offensive, especially in warm weather. So far as our observations have gone, such growths flourish best in a mixture consisting partly of unpurified sewage liquor and partly of oxygenated and nitrated water or effluent.

This is illustrated by some channel experiments at Chorley, which we began towards the end of February, 1907. One of the channels carried a mixture of 75 volumes of filter effluent and 25 volumes of well-clarified precipitation tank liquor. The mixture gave the following average figures of analysis :—

Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal nitrogen (1·34 to 3·6)	2·2	4
Albuminoid nitrogen (0·14 to 0·20)	0·16	3
Oxidized nitrogen (1·76 to 2·32)	2·2	3
"Oxygen absorbed" in 4 hours (0·81 to 2·21)	1·4	6
Dissolved oxygen taken up from water *in 5 to 8 days* (0·65 to 2·81)	1·4	6
Dissolved oxygen taken up from water *in 24 hours* (0·18 to 1·16)	0·8	3
Incubator test (by smell)	All passed.	6

In spite of these comparatively good figures, and the fact of the liquid being non-putrescent upon incubation, the channel was, in June, 1907, filled from end to end with a thick grey fungoid growth.

Another channel, conveying purified filter effluent, had only a green growth, coated to some extent with effluent solids, while a third channel which carried filter effluent plus a proportion of storm water equivalent, *on the average*, to 30 per cent. of the total volume of liquid delivered to the channel, became full of black putrescent mud, but had little or no sewage fungus.

We are not at present in a position to state with certainty, by reference to figures of analysis, what effluents will, and what effluents will not, cause objectionable growths in streams.

Nitrates in Effluents.

324. Although a well nitrated effluent usually takes up dissolved oxygen from water slowly, this is not always the case. The following effluent (from a strongly ammoniacal sewage) is an instance of this variation :—

	Parts per 100,000.
Ammoniacal nitrogen	13·02
Albuminoid nitrogen	0·48
Nitrous nitrogen	0·26
Nitric nitrogen	4·70
Solids in suspension	Trace.
"Oxygen absorbed" at 27° C. (80° F.) *at once*	1·96
"Oxygen absorbed" at 27° C. (80° F.) in 4 hours	5·62
Dissolved oxygen taken up from water at 18°C. (65°F.)	
(*a*) in 24 hours	0·89
(*b*) in 48 hours	2·16
Incubator test (by smell)	Passed.

Here, although there are about five parts of oxidised nitrogen present in the liquid, there still remains a considerable quantity of readily oxidizable organic matter. Conversely, instances might be given of effluents, poor in nitrate, which took up very little dissolved oxygen from water.

Chemical Poisons in Effluents.

325. We have not yet studied this point in much detail, but we think that very few effluents in which the organic matter had been well oxidized, would contain chemical poisons in quantity sufficient to do harm to fish life, and that the heavy metals would be brought down in the sludge. When the Leeds sewage was known to contain a considerable quantity of arsenic, the effluents from its biological filtration showed only minute traces of it.

Cases may occur where chlorine compounds, acids, or alkalies, might be present in an effluent. We have heard, for instance, of the addition of lime, for the purpose of temporarily sterilizing a poor effluent; such effluents would of course be detrimental to fish.

The Relation of certain Tests to One Another

326. Dr. McGowan has made a careful comparison of the figures of analysis of 163 effluents of varying degrees of purity and obtained by various artificial processes. In most of the cases a determination was made of the dissolved oxygen taken up by the effluent from water in twenty-four hours, as well as of the "oxygen absorbed" from permanganate, etc.

As a result of this comparison we find that:—

(1) The figures for albuminoid nitrogen and for "oxygen absorbed" from (strong) permanganate in four hours show a close parallelism, but bear no constant ratio to one another. In well, or fairly well, purified effluents, comparatively free from suspended solids, the ratio will usually be something like one part of albuminoid nitrogen to ten parts of "oxygen absorbed" in four hours at 27° C. (80° F.).

(2) The ratio of albuminoid to total organic nitrogen in an effluent is usually from 1 : 2 to 1 : 3, though it may in certain cases be either below or above those figures. When an effluent contains a large quantity of suspended solids, the ratio tends to be high.

(3) There is nothing like a definite ratio between the figures for albuminoid (or total organic) nitrogen and ammoniacal nitrogen in an effluent. The actual quantity of free ammonia left in an effluent, especially if it be compared with that in the original sewage or tank liquor, furnishes, however, a very valuable indication of the extent to which oxidation has been promoted by the filter.

(4) The ratio of "oxygen absorbed" at once from (strong) permanganate to "oxygen absorbed" in four hours is usually fairly constant at about 1 : 3 to 1 : 4, though there are a good many exceptions.

The main object of the test—"oxygen absorbed" at once (or in three minutes)—is to show whether there is an abnormal quantity of quickly oxidisable matter, whether organic or inorganic, in a sewage liquid. It cannot be regarded as a substitute for the four hours test.

(5) The ratio of dissolved oxygen taken up from water in twenty-four hours at 18° C. (65° F.) to "oxygen absorbed" from permanganate in four hours at 27° C. (80° F.) shows very wide variations, and the figures cannot be said to bear much relation to one another, except in a very general way. When the ratio is low, the effluent is more often than not of poor quality. With a high ratio —say, over 1 : 5—the effluent is almost always a good one.

(6) The ratio of dissolved oxygen taken up in *twenty-four hours* to "oxygen absorbed" from permanganate *at once* varies very much also; as a general rule the better effluents show the higher ratios.

The Relation between the Incubator or Non-putrescibility Test and the taking up of Dissolved Oxygen from Water.

327. There is no certain correspondence between the results of these two tests. An artificial effluent, made by adding excess of nitrate to a diluted sewage, takes up dissolved oxygen at a rapid rate, but the nitrate prevents it from putrefying upon incubation.

At the same time we find that when an effluent is pretty well purified, there is fairly definite relationship between the two tests.

Of the 163 effluents of varying degrees of purity which were examined by Dr. McGowan, 107 did not putrefy on incubation ; forty-nine putrified ; and seven were doubtful.

Of the 107 effluents which did not putrefy on incubation, ninety-eight were tested for dissolved oxygen absorption, and were found to take up an average of 0·57 part per 100,000 in 24 hours. The figures ranged from 0·0 to 3·2 parts per 100,000, and in most of the cases where a high figure was obtained, there was much suspended solid in the effluent. There were thirty-five effluents which contained over 3 parts of suspended solids per 100,000 (the average being 7·1 parts), and these took up an average of 0·85 part of dissolved oxygen in 24 hours. The remaining sixty-three effluents, which contained 3 parts or less of suspended solids per 100,000, took up an average of 0·41 parts of dissolved oxygen. Again, of nineteen of the effluents which did not putrefy on incubation, but which seemed of somewhat indifferent quality as judged by the figures of analysis, only five took up more than 1 part of dissolved oxygen.

Of the forty-nine effluents which putrefied on incubation, thirty-three were tested for dissolved oxygen absorption, and were found to take up from 0·57 to 7·0 parts (or an average of 2·3 parts) of oxygen from water in 24 hours.

We may summarise the position as follows :—

(1) It is very rare indeed for an effluent which (apart from suspended solids) takes up little dissolved oxygen from water to fail upon incubation.

(2) It is comparatively infrequent for an effluent (apart from suspended solids) which withstands incubation to take up dissolved oxygen from water at a rapid rate.

(3) In the great majority of cases an effluent which fails to withstand the incubator test will also take up much dissolved oxygen from water ; and

(4) An effluent which takes up much dissolved oxygen from water will also usually fail upon incubation.

Both these tests depend upon the fermentative changes which may take place in an effluent, on keeping, but a standard based upon a low figure of dissolved oxygen absorption would, in some cases, be more stringent than a standard of non-putrescibility alone.

328. It is, we think, probable that an effluent which does not take up dissolved oxygen from the water of a stream more rapidly than that water can naturally re-aerate itself from the air, would neither give rise to unpleasantness nor—assuming the absence of chemical poisons—injure fish life, but this is a point on which we shall be able to speak more definitely after the conclusion of our observations on streams.

* *Condition of Effluent as regards Aeration.*

329. In some circumstances the question of the amount of dissolved oxygen contained in the effluent would be of importance. If the effluent were almost completely de-aerated, as many contact bed effluents are, and were to be discharged into a stream, the volume of which was small as compared with the volume of effluent, the mere admixture of stream and effluent would, at all events near the point of discharge, produce a liquid in which the amount of dissolved oxygen would be far below the saturation point.

It should be added that it would probably not be difficult to aerate a contact bed effluent previous to its discharge into the stream.

Effluents from percolating filters are usually well aerated.

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* See also Report by Dr. Letts and Dr. Adeney. Appendix VI.

PART VII.—POLLUTION OF ESTUARIES AND TIDAL WATERS.

330. In our fourth report we dealt with the question of the pollution of tidal waters, with special reference to contamination of shell-fish.

As regards the standard of effluent that can be permitted for tidal waters, having regard to the reasonable protection of salmon fisheries and the avoidance of nuisance, we stated that we did not think it practicable to lay down any fixed rules, as the necessities of each case would depend on a variety of considerations. We were, however, of opinion that in certain circumstances sewage should be purified before it is discharged into tidal waters.

We therefore proposed that the Rivers Board should be empowered, subject to appeal to the Central Authority, to call upon a local authority to adopt some method of purification in cases where purification was necessary.

331. Professor Letts and Dr. Adeney kindly agreed to collect and collate the results of investigations bearing on the question of standards for tidal waters, as regards offensive putrefaction, and injury to fish, and they have presented to us a report on this subject which is contained in Appendix VI.

Their report contains the results of much original work as well as the results, which they have brought together, of the work done by other observers.

Professor Letts and Dr. Adeney have devoted a large amount of time to the work, and we are greatly indebted to them for their report, which is a document of considerable value.

The report affords further proof that any provisions which may be enacted for dealing with the pollution of tidal waters must be of an elastic character.

As an appendix to the report, Dr. Gilbert Fowler has supplied a memorandum as to the results of some observations which he made as to the discharge of septic tank sludge into an estuary near Ipswich.

PART VIII.—SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

(I) PREVIOUS REPORTS.

Interim Report. Cd. 685 [1901].

332. Our first Report was of an interim character and contained the following conclusions :—

(1) No land is entirely useless for purification of sewage, "but in the case of stiff clay and peat lands "the power to purify sewage seems to depend on the depth of the top soil."

"There are, of course, numerous gradations in the depths of top soil which are met with in nature, and "it is not easy to draw the line between lands which contain a sufficient depth to justify their use, and lands "which do not."

"We are, however, forced to conclude that peat and stiff clay lands are generally unsuitable for the "purification of sewage, that their use for this purpose is always attended with difficulty, and that where "the depth of top soil is very small, say 6 inches or less, the area of such lands which would be required "for efficient purification would in certain cases be so great as to render land treatment impracticable."

(2) ". . . we are satisfied that it is practicable to produce by artificial processes alone either from sewage, "or from certain mixtures of sewage and trade refuse, such, for example, as are met with at Leeds and Manchester, effluents which will not putrefy, which would be classed as good according to ordinary chemical "standards, and which might be discharged into a stream without fear of creating a nuisance."

"We think, therefore, that there are cases in which the Local Government Board would be justified "in modifying, under proper safeguards, the present rule as regards the application of sewage to land."

(3) ". . . as a result of a large number of examinations of effluents from sewage farms and from artificial "processes we find that while in the case of effluents from land of a kind suitable for the purification of sewage "there are fewer micro-organisms than in the effluents from most artificial processes, yet both classes of "effluents usually contain large numbers of organisms, many of which appear to be of intestinal derivation, "and some of which are of a kind liable, under certain circumstances at least, to give rise to disease."

"We are of opinion, therefore, that such effluents must be regarded as potentially dangerous, and we "are considering whether means are available and practicable for eliminating or destroying such organisms, "or, at least, those giving rise to infectious diseases."

(4) "It is of the utmost importance that the simplest possible means should be provided for adequately "protecting all our rivers," . . . and "it will be desirable, probably for some time to come, that scientific "experiments should be carried on in order to ascertain all the real dangers of pollution, against which they "should be protected."

"In the present state of knowledge, and especially of bacteriology, it is difficult to estimate these dangers "with any accuracy, and it seems quite possible that they should be either exaggerated or under-valued "according to the pre-disposition of those who have to deal with them. An authority, guided by medical "considerations, might not unnaturally be inclined to insist on a degree of purity which may ultimately "prove in certain cases to be uncalled for, while another authority, with its mind fixed upon economy, "might shrink from taking essential precautions."

. . . "the general protection of our rivers is a matter of such grave concern as to demand the "creation of a separate Commission, or a new department of the Local Government Board, which shall be "a Supreme Rivers Authority, dealing with matters relating to rivers and their purification, and which, "when appeal is made to them, shall have power to take action in cases where the local authorities have "failed to do so."

Second Report. Cd. 1178 [1902].

333. Our second Report was a formal document covering certain scientific papers which were presented as an appendix to that Report.

Third Report. Cd. 1486 [1903].

334. In our third Report we dealt with the relations between local authorities and manufacturers in regard to the disposal of manufacturing effluents. We found that the present state of the law was most unsatisfactory, that the attitude of local authorities towards manufacturers had differed widely, and that many manufacturers were seriously handicapped. Our investigations showed that purification of trade effluents by the local authority is in the great majority of cases practicable ; purification by the manufacturer is in some cases difficult, if not impracticable ; while purification by the manufacturer would generally be more costly than purification by the local authority.

It also appeared that the local authorities, as well as the manufacturers, were of opinion that there should be laid on the local authority a distinct obligation to receive trade effluents.

335. Our recommendations on this point were as follows :—

"We are, therefore, of opinion that the law should be altered so as to make it the duty of the local "authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and "that the manufacturer should be given the right, subject to the observance of certain safeguards, to dis- "charge trade effluents into the sewers of the local authority if he wishes to do so."

"We do not think it possible to provide, by direct enactment, what these safeguards should be. In "each district it would probably be desirable that the local authority should frame regulations which should "be subject to confirmation by a Central Auuthority. In most cases however, these regulations could provide "definite standards for the different manufacturers as regards preliminary treatment, and it appears from "the evidence that manufacturers would much prefer to have standards to work to."

"Power to vary the standards or to dispense with them altogether in special cases would be necessary."

"Although the duty of receiving trade effluents should, we think, be imposed on the local authority, "cases may arise in which they should be wholly or partially relieved of it."

"For example, we find that in some instances the effluent discharged from the manufactory is of a com- "posite character, the greater part of which might with advantage be easily dealt with by the manufacturer "if it were kept separate. In such cases we think the manufacturer would generally be willing to adopt "this course, but provision is necessary for those cases in which the local authority and manufacturer could "not agree."

"Further, although we have received no conclusive evidence to show that there are trade effluents which "could not be purified by the local authority, we do not deny the possibility of such cases arising."

"And it is possible that in some cases, as, for example, of a large manufactory being newly established in "a small district, it might be necessary to relieve the authority of the obligation to treat the trade effluent "or to enable them to exact some special contribution from the manufacturer, not only for the cost of treat- "ment, but also towards capital expenditure."

"It is obvious, therefore, that some tribunal will be required for settling differences between the local "authority and the manufacturer, and for relieving the local authority in exceptional cases, either wholly "or partially, of their obligation to provide sewers and disposal works of sufficient capacity for trade effluents "as well as ordinary sewage."

"We are of opinion that generally no special charge should be made on the manufacturer in those cases "in which the regulations as to preliminary treatment are complied with."

"As we have already stated, it is desirable that, wherever practicable, some preliminary treatment "should be carried out by the manufacturer."

"But where the manufacturer is unable to comply with these regulations we consider that the local "authority should be empowered to make a special charge."

"Power should also be granted to make a special charge, even when preliminary treatment is adopted, "where there are exceptional circumstances as regards volume, quality or otherwise."

Settlement of Differences Between Local Authorities and Manufacturers.

336. The chief questions upon which we considered that differences might arise were :—

(1) The refusal of a local authority to allow a particular trade effluent to enter their sewers.

(2) The refusal of a local authority to construct or enlarge sewers for the purpose of a particular manufactory.

(3) The question of varying general regulations as to preliminary treatment by the manufacturer.

(4) The amount of the special charge to be imposed on the manufacturer.

(5) The removal of sludge.

The balance of opinion we found to be strongly in favour of the view that for the settlement of these questions it is necessary to constitute a Central Board possessing adequate technical knowledge, such as the Supreme Rivers Authority which we recommended in our Interim Report.

As regards this matter we reported as follows :—

"We have been struck by the large sums which have been expended in appeals to Courts, but apart "from the question of expense we are strongly of opinion that the ordinary Courts are not suitable for the "determination of these questions, and we venture to think that the judgment of the Master of the Rolls "in the case of Attorney-General *v.* Whitmore, to which we have already referred, clearly supports this view. "His comment that 'the evidence was very complicated, the expert witnesses who were called not only giving "evidence quite inconsistent with one another, but some of them giving evidence in cross-examination which "was quite inconsistent with what they said in examination in chief,' might apply to many similar cases."

"The scientific questions to be solved would in most instances be capable of actual determination by "a properly-equipped Central Authority, and there can be little doubt that such direct proof would be far "less costly than the process of endeavouring to arrive at the truth through the evidence of expert witnesses "in a Court of Law."

"Moreover, the matters to be determined include, not only scientific questions on which witnesses may "be expected to differ, but also considerations of an administrative character which should more properly "be dealt with by a Government Department."

"Further, we find that a Central Authority possessing adequate technical knowledge, would command "the confidence of local authorities and manufacturers."

"In our opinion a properly equipped central authority is essential, and we unhesitatingly recommend "the creation of such an authority."

"In the interests of river purification as well as of the trade of the country we consider it is of the highest "importance that the changes in the law which we have recommended should be made. But these changes "would not in our opinion, be of much use apart from the creation of a Central Authority for the determination "of differences between the local authority and the manufacturer."

"If the settlement of these differences be left to the ordinary Courts, differential treatment of manu- "facturers, with all the objections to it, will be certain to continue."

We also recommended that, for the due protection of rivers, River Boards should be formed for other parts of the country, similar to the three which already exist in Lancashire and Yorkshire, and that these boards should be empowered to determine, subject to appeal to the Central Authority, certain of the differences between local authorities and manufacturers.

We further advised that it should be the duty of Rivers Boards to inspect public water supplies and to report to the Central Authority any cases of dangerous pollution of such supplies which they may detect; and that the Central Authority should be empowered, after due inquiry, to order the purveyors of the water to adopt such means as, in the opinion of the Central Authority, were reasonable and necessary for removing or diminishing the danger.

We also recommended that the Central Authority might, with the aid of the Rivers Boards, very properly collect such information as is available throughout the country in regard to waste of water by pumping from mines, and in regard to the abstraction of water from one district, for the supply of another district, to the detriment of the water supply of the district from which the water was taken. We consider that the collection of such information should precede the consideration of the question whether legislative interference in regard to these matters is desirable.

Fourth Report. Cd. 1883 [1904].

337. In our fourth Report, we dealt with the pollution of tidal waters, with special reference to the contamination of shell-fish. We stated that:—

"After carefully considering the whole of the evidence on this point, we are satisfied that a considerable "number of cases of enteric fever and other illness are caused by the consumption of shell-fish which have "been exposed to sewage contamination; but in the present state of knowledge, we do not think it possible "to make an accurate numerical statement, at any rate as regards the whole country."

"There can, however, be no doubt that the evil is sufficiently grave to demand a remedy."

Our main recommendation for dealing with the evil was stated in the following terms:—

"After carefully considering the whole of the evidence, together with the results of our own investiga- "tions and local inquiries, we are strongly of opinion that the only way in which this evil can be effectively "dealt with is by placing tidal waters under the jurisdiction of a competent authority, and conferring on "that authority power to prevent the taking of shell-fish for human consumption from any position in which "they are liable to risk of dangerous contamination, and to enforce restrictions as regards pollution, and "as regards waters, foreshores, pits, ponds, beds and layings in which shell-fish are fattened or stored, as and "when required."

"For this purpose the powers of the authority must be elastic. The case of each river and estuary is a "problem by itself, and it would not be practicable to fix by enactment any standard or standards which would "be generally suitable to the widely different conditions of different cases. Moreover, as the conditions are "shifting in character, it is necessary to provide some permanent machinery by which restrictions can be "varied."

After considering various alternative suggestions as to the Controlling Authority, we stated that:—

"We entirely agree with the view which has been pressed upon us by a large number of witnesses that "Rivers Boards would be the most suitable bodies in whom to vest the local control which we are now dis- "cussing. Their control over inland waters is of a similar character to the control which is required over "tidal waters (estuarial and other), and it is desirable and fitting that their jurisdiction should be extended "to tidal waters for public health purposes. There are indeed no other local bodies possessing the "necessary qualifications, and the only practicable alternative to giving them jurisdiction would seem to "be to place the whole control in the hands of a Central Department."

We recommended therefore :—

"That the necessary power of control over the pollution of tidal waters, and over waters, foreshores, "pits, ponds, beds, and layings where shell-fish are grown, fattened or stored, should be vested in the Rivers "Boards, subject to appeal to a central authority."

In the Report we set forth, in detail, the procedure which the Rivers Boards and Central Authority should follow. We also dealt with the question of the means which should be adopted for avoiding danger from the consumption of foreign shell-fish.

As regards other evils, besides the contamination of shell-fish, which had to be guarded against in the case of discharge of sewage into tidal waters, we made recommendations dealing with these matters.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

(2) PRESENT REPORT.

General Conclusion.

338. It is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters, and there is no essential difference between the two processes. Page 9.

The main questions, therefore, to be considered in the case of a town proposing to adopt a system of sewage purification are, first, what degree of purification is required in the circumstances of that town, and of the river or stream into which its liquid refuse is to be discharged; and, secondly, how the degree of purification required can, in the particular case, be most economically obtained.

Removal of Suspended Matters.

We find that it is generally desirable to remove from the sewage, by a preliminary process, a considerable proportion of the grit and suspended matters, before attempting to purify the sewage on land or filters. Page 18.

Sedimentation Tanks.

339. *Quiescent Sedimentation.*—Two to three hours quiescence is usually sufficient to produce a tank liquor fairly free from suspended solids, but owing to the fact that some sewages contain a larger proportion than others of solids that settle very slowly, no general rule can be laid down as to the necessary period of quiescence. With this form of treatment the deposit in the tanks should be frequently removed. Page 19.

Continuous Flow Sedimentation.—The amount of settlement effected does not depend alone upon the period of flow, but upon a number of other factors. If the tank liquor is to be treated upon filters of fine material, the period of flow should generally be from 10 to 15 hours. The tanks should be cleaned out at least once a week. Page 20

Septic Tanks.

340. All the organic solids present in sewage are not digested by septic tanks, the actual amount of digestion varying with the character of the sewage, the size of the tanks relative to the volume treated, and the frequency of cleansing. With a domestic sewage, and tanks worked at a 24-hours rate, the digestion is about 25 per cent. Page 21.

The liquor issuing from septic tanks is bacteriologically almost as impure as the sewage entering the tanks. Page 22.

Domestic sewage which has been passed through a septic tank is not more easily oxidised in its passage through filters than domestic sewage which has been subjected to chemical precipitation or simple sedimentation. Page 22.

Page 25. No definite rules can be laid down as to how long a septic tank should be run without cleaning. In the case of small sewage works (serving populations of say 100 to 10,000 persons), the tanks should generally be allowed to run, without cleaning, so long as the suspended matter in the tank liquor shows no signs of affecting the filters injuriously. For larger works it would generally be advisable to run off small quantities of sludge at short intervals of time.

Page 26. The rate of flow through a septic tank is a matter in which the needs of each place require special consideration, but at few places should the sewage be allowed to take longer than 24 or less than 12 hours to flow through the tank. In no case should less than two tanks be provided, and they should be arranged so that, if necessary, one tank can be used alone.

Page 28. As regards digestion of sludge and quality of tank liquor, a closed tank possesses no advantages over an open tank. There is less risk of nuisance if the tank and the feed channels to the filters are covered in.

Page 29. By passing septic tank liquor through tanks of a size sufficient to hold about one quarter of the day's flow, with the addition of from 2 to 3 grains of lime per gallon to the liquor, the suspended solids in the liquor are materially reduced, a considerably larger quantity of the liquor can be treated per cube yard of filter, and the offensive character of the liquor is largely destroyed.

Chemical Precipitation.

Page 30. 341. In the case of sewages which contain certain trade waste, and strong sewages from water-closet towns, it is generally desirable to subject the sewage to some form of chemical treatment before attempting to oxidise the organic matter contained in it. In most cases careful chemical precipitation materially aids the deposition of the suspended solids, and facilitates subsequent filtration.

Page 30. No general rule can be stated with regard to the capacity of precipitation tanks. With continuous flow, an eight hours rate is usually sufficient to produce a fairly good tank liquor from a domestic sewage of average strength.

Page 30. If sewage is allowed to remain quiescent in the tank, two hours settlement would usually suffice.

Relative Cost of Different Tank Treatments.

Page 43. 342. In the absence of special circumstances favouring a particular plan, it would appear that there is very little difference in annual cost between the various methods of tank treatment when taken in conjunction with the cost of subsequent filtration through percolating filters, assuming that the kind of filter adopted in each case is that which is best adapted to the particular tank treatment provided.

Filters.

Page 52. 343. Within ordinary limits, the depth of a contact bed makes, practically, no difference to its efficiency per cube yard.

Page 53. We think that it would be generally inadvisable to construct contact beds of a greater depth than 6 feet or of a less depth than 2 feet 6 inches.

Page 87. For practical purposes and assuming good distribution, the same purification will be obtained from a given quantity of *coarse* material, whether it is arranged in the form of a deep or of a shallow percolating filter, if the volume of sewage liquor treated per cube yard be the same in each case.

Page 87. With regard to percolating filters of *fine* material, if the liquid to be purified were absolutely free from suspended and colloidal solids, and if thorough aeration could be maintained, the statement just made for filters of coarse material might possibly hold good for filters of fine material also. In practice, however, these conditions can scarcely be maintained with large rates of flow, and we think that the greatest efficiency can be got out of a given quantity of *fine* material by arranging it in the form of a shallow filter rather than of a deep filter. But we are not in a position to make an exact quantitative statement as to the difference in efficiency of the two forms.

344. The amount of sewage which can be purified per cube yard of contact bed or of percolating filter varies—within practical limits—nearly inversely as the strength of the liquor treated. This statement is based on the assumption that the size of the material of which the filter is composed is, in each case, suitable to the character of the liquor treated, and that the material is arranged at the proper depth to secure maximum efficiency. Page 119.

Detailed particulars as to the amounts which can be treated per cube yard of filter are given on page 117.

Taking into account the gradual loss of capacity of contact beds, a cubic yard of material arranged in the form of a percolating filter will generally treat about twice as much tank liquor as a cubic yard of material in a contact bed. Page 119

In the case of sewage containing substances which have an inhibitory effect upon the activity of micro-organisms, the working power per cube yard of filter of either type may be more nearly equal. This point, however, is not clearly established. Page 119.

Percolating filters are better adapted to variations of flow than contact beds. Page 119.

Effluents from percolating filters are usually much better aerated than effluents from contact beds, and, apart from suspended solids, are of a more uniform character. On emptying a contact bed, the first flush is usually much more impure than the average effluent from the bed. Page 119.

The risk of nuisance from smell is greater with percolating filters than with contact beds. Page 119.

With percolating filters there is apt to be nuisance from flies, especially with filters constructed of coarse filtering material. In the warmer months of the year, such filters swarm with members of the *Psychodidae*, which, though appearing to breed and develop in the filters, may usually be seen in large numbers on the walls of houses, or buildings close to or on the works. Page 119

Treatment of Sewage on Land.

345. There is no essential distinction between effluents from land and effluents from artificially constructed filters. Pages 137 and 142.

Effluents from those soils which are particularly well adapted for the purification of sewage contain only a very small quantity of unoxidised organic matter, and are usually of a higher class than effluents from artificial filters as at present constructed and used. Page 142.

Effluents from soils which are not well adapted for the purification of sewage may often be very impure. Page 142.

Sludging of Mill Dams.

346. In any case in which the Rivers Board should be of opinion that the sludging of a mill dam by turning the accumulated sludge into the stream would give rise to a nuisance, and that it would be financially practicable for the mill owner to adopt some other method of cleansing the dam, the Rivers Board should be empowered, by notice, to direct the mill owner not to turn the sludge into the stream. Page 191.

It should be provided that any mill owner deeming himself aggrieved by such a direction, might, within some fixed period, appeal to the Central Authority. The decision of the Central Authority should be final.

Should any cases arise, in which it is important that the sludge should not be turned into the stream, but in which the Rivers Board are of opinion that the cost of adopting any other method of cleansing the dam would be prohibitive to the millowner, we recommend that the Rivers Board should be empowered to represent the case to the Central Authority, and that the Central Authority should be empowered. after due enquiry, to direct that the sludge shall not be turned into the stream. If the Central

Authority should be satisfied that the cost of adopting some other method of cleansing the dam would be greater than the millowner could be reasonably called upon to bear, they should be empowered to direct that a portion of the cost should be borne by the local authorities whose districts would be benefited.

Effect of Trade Effluents on Sewage Purification.

Page 192. 347. All the trade effluents of which we have had experience interfere with or retard processes of purification to some extent, but we are not aware of any case where the admixture of trade refuse makes it impracticable to purify the sewage upon land or by means of artificial processes, although in certain extreme cases special processes of preliminary treatment may be necessary.

Nuisance from Smell.

Page 195. 348. All sewage works are liable, at times, to give off unpleasant smells ; they should, therefore, be situated away from dwelling houses, wherever this is practicable.

The nuisance is apt to be considerably greater where the sewage contains brewery refuse in any quantity ; but, on the other hand, the presence of some trade effluents, such, *e.g.*, as iron salts or tarry matters, tends to render the process of purification less offensive.

The extent of the risk of nuisance depends, however, not only on the character of the sewage, but also on the method of treatment adopted.

General Observations bearing on Choice of a Method of Sewage Treatment.

Page 202. 349. The selection of a method of sewage disposal should depend primarily on local conditions.

If a sufficient quantity of good land, to which the sewage can gravitate, can be purchased for about £100 an acre, land treatment would usually be the cheapest method to adopt.

In cases where only clay land is available, it would generally be cheaper and more satisfactory to provide artificial filters.

Page 202. 350. Given conditions favourable to each process, there is little difference as regards cost between any of the different forms of tank treatment when these are considered along with the cost of subsequent filtration.

Page 202. Single contact will, generally, only yield a good effluent where the sewage to be treated is weak, and then only after good preliminary treatment. For the purification of partially settled weak sewage, and for well, as also for partially, settled sewage of average strength, if the case is one in which a good effluent is required, double contact is necessary, while if a strong sewage has to be treated, triple contact is necessary, unless the preliminary treatment is exceptionally good.

Page 203. In nearly every case a greater rate of filtration per cube yard can be adopted if the material is arranged in the form of a percolating filter, than if it is used in contact beds. In many cases the rate of filtration through percolating filters may be double or nearly double what it could be with contact beds.

Pages 67 & 203. Where the liquor to be treated contains much suspended matter, it is usually advisable to construct filters, whether contact or percolating, with coarse filtering material. Where the preliminary treatment has effectively removed the greater part of the suspended matter, it is best to use fine material in the filters.

Storm Overflows on Branch Sewers.

Page 209. 351. Storm overflows on branch sewers should be used sparingly, and should usually be set so as not to come into operation until the flow in the branch sewer is several times the maximum normal dry weather flow in the sewer. No general rule can be laid down as to the increase in flow which should occur in the branch sewers before sewage is allowed

to pass away by the overflow untreated. The Rivers Board, or in districts where there is no Rivers Board, the County Council, should have power to require the local authority to alter any storm-overflows which, in their opinion, permit of an excessive amount of unpurified sewage to flow over them. The local authority should have the right to appeal to the Central Authority in any case in which they consider that the requirement of the Rivers Board is unreasonable or impracticable of fulfilment.

The general principle should be to prevent such an amount of unpurified sewage from passing over the overflow as would cause nuisance.

Treatment of Storm Water Sewage at the Works.

352. As a general rule, special stand-by tanks (two or more) should be provided at the works, and kept empty for the purpose of receiving the excess of storm water which cannot properly be passed through the ordinary tanks. As regards the amount which may be properly passed through the ordinary tanks, our experience shows that in storm times the rate of flow through these tanks may usually be increased to about three times the normal dry weather rate without serious disadvantage. Page 210.

The overflow at the works should be made from these special tanks, and should be arranged so that it will not come into operation until the tanks are full.

Special filters which are only used in times of storm are not usually efficient, and should not be provided.

Any extra quantity of sewage arriving at the works in storms, which has to be filtered, should be treated on the ordinary filters, which should be made sufficiently large for the purpose.

As regards the size of the stand-by tanks, the amount of storm water sewage to be filtered, and the arrangements generally for dealing with the storm sewage at the outfall works, the Rivers Board or the County Council in areas in which no Rivers Boards have been established, should have similar power to that which we have proposed in regard to overflows on branch sewers, and the local authority should have a similar right of appeal to the Central Authority.

In most cases it will probably suffice to provide stand-by tanks capable of holding one quarter of the daily dry weather flow, and it will not be necessary to provide for *filtering* more than three times the normal dry weather flow.

Under the arrangements which we recommend no storm sewage arriving at the outfall works would be discharged without some settlement.

Separate Systems of Sewers.

353. In any case in which a local authority wishes to adopt the separate system of drainage for the whole or any part of their district, they should apply to the Central Authority, and that Authority should be empowered to confer on the local authority, by order, such powers as are required. Page 216.

As regards the powers that are required, the provisions which are generally contained in local Acts in respect of this matter seem to be defective. If separate sewers are provided, the local authority should have a clear power to enforce the provision of separate drains, but the local Acts to which our attention has been drawn do not modify the powers of the local authority under the general law in regard to bye-laws as to the drainage of houses. Moreover, the powers of the local authority should not necessarily be limited to new streets and new houses.

As a general rule, the expense of altering existing drains should fall on the local authority, and there may be some instances in which it would be equitable that they should bear some portion of the additional cost even in the case of new roads.

The Central Authority should, therefore, have power to include in their Order such provisions for the allocation of the cost as they consider equitable, having regard to the local circumstances.

Standards for Sewage Effluents.

Page 218. 354. Our terms of reference require us to have regard to the "*economical* and efficient" discharge of the duties of local authorities, and in view of the importance of not requiring a local authority to incur any further expenditure on sewage disposal than the circumstances of its area require, we feel strongly that the law should be altered so as to allow local circumstances to be taken into account.

Page 220. We recommend that the Central Authority should determine the nature of the tests which are to be applied for the purpose of standards, and that it should be made the duty of the Rivers Board, or of the County Council in areas not under the jurisdiction of a Rivers Board, to determine, from time to time, subject to appeal to the Central Authority, what standards should be adopted.

In the first instance it would be convenient that the Central Authority should prescribe one standard for all non-tidal waters, in place of the existing statutory provisions. It would then rest with the Rivers Board or County Council to fix, subject to appeal to the Central Authority, a higher or lower standard in any case in which they were of opinion that the circumstances required or justified a different standard.

We further recommend that no action should be allowed to be brought in respect of damage alleged to be due to the discharge of an effluent which complies with the standard fixed for the water into which it is discharged, but that in such cases complaint should be made to the Central Authority, and, if a *prima facie* case is made out, that Authority should ascertain whether the complaint is well founded, and should be empowered to fix a different standard if the circumstances are shown to require it.

In cases where it is alleged that the effluent does not comply with the statutory standard, and that damage is caused by the discharge of such effluent, action should be brought in the ordinary Courts.

But any questions arising as to whether the effluent complies with the statutory standard, or as to whether the damage has been caused by the discharge of the effluent in respect of which complaint is made, should be referred by the Court to the Central Authority for determination. The costs of such determination should be borne by the parties to the action in such proportions as the Court may determine.

Power should be conferred on the Central Authority to suspend, from time to time, the operation of any standard, to allow time for the construction of works, or for any other reason which, in their opinion, justified such suspension.

Tests for Sewage Effluents in Relation to Standards.

Page 222. 355. According to our present knowledge, an effluent can best be judged by ascertaining, first, the amount of suspended solids which it contains, and, second, the rate at which the effluent, after the removal of the suspended solids, takes up oxygen from water.

In applying this test it is important that the suspended solids should be removed, and estimated separately.

For the guidance of local authorities we may provisionally state that an effluent would generally be satisfactory if it complied with the following conditions:—

(1) That it should not contain more than 3 parts per 100,000 of suspended matter; and

(2) That, after being filtered through filter paper, it should not absorb more than:

(*a*) 0·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 24 hours.

(*b*) 1·0 part by weight per 100,000 of dissolved or atmospheric oxygen in 48 hours; or

(*c*) 1·5 parts by weight per 100,000 of dissolved or atmospheric oxygen in 5 days.

The Central Authority.

356. To secure the economical and efficient discharge of the duties of local authorities, and others, in regard to pollution, and adequately to protect the public health and the amenities of rivers, the statutory provisions in regard to these matters must be of an elastic character.

The conditions of different cases vary to such an extent that the necessary control cannot, in our opinion, be provided by any direct enactment which could be enforced by the ordinary Courts.

Throughout our Reports, this fact has been fully recognised, and we have proposed, in regard to many matters, that ultimate control should be vested in an adequately equipped Central Administrative Authority, and that, as far as practicable, the local Rivers Board should, in accordance with regulations framed by the Central Department, act as a first tribunal.

Among the more important questions which have to be dealt with under the new conditions of administration which we are contemplating, are the following :—

(i.) Disputes between local authorities and manufacturers as to the terms and conditions on which trade effluents shall be admitted into sewers ;

(ii.) The control of shell-fish layings so as to prevent the taking of shell-fish for human consumption from positions in which they are liable to risk of dangerous contamination.

(iii.) The protection of water supplies from pollution.

(iv.) The collection of information as to the water supplies available in various parts of the country.

(v.) The collection of information as to the need of water in various parts of the country.

(vi.) The settlement of standards for different reaches of water.

(vii.) Conferring powers on local authorities, in suitable cases, to provide separate systems of sewers for surface water and to enforce the provision of separate drains.

(viii.) The settlement of questions as to the extra amount of sewage which a local authority should be required to treat during storms.

There are also numerous questions in regard to the purification of polluting liquids which, in the interests of the public, have still to be worked out, and it is essential that the Central Authority should be properly equipped for undertaking such special investigations as they may from time to time find necessary, and for collecting and collating the work done by others.

Since the date of our appointment considerable developments have taken place in regard to the disposal of sewage, and there is every reason to think that further changes will occur in the future.

Unless the Central Department keep in close touch with all such changes, and from time to time report on them, it is not possible for local authorities throughout the country fully to utilise the results of valuable work which is being done at many places, and hence, to perform their duties in the most economical as well as efficient manner.

The Position of our Inquiry.

357. In this Report we have dealt with the main question of what methods of sewage disposal may properly be adopted by local authorities. The remainder of our work will be chiefly concerned with the disposal of trade effluents when not mixed with sewage.

We have already investigated the disposal of distillery effluents, and shall issue a separate Report on this subject very shortly.

Concurrently with our investigation of the methods available for disposing of other trade effluents we shall continue our observations on the effect of discharging effluents of known composition into streams, with a view to reporting more fully on the question of standards and tests.

Page 188. We are continuing, for another season, the experiments on the manurial value of sewage sludge, and are also making some observations on a few other points.

IDDESLEIGH (*Chairman*),
T. WALTER HARDING,
WILLIAM RAMSAY,
W. H. POWER,
T. J. STAFFORD,
REGINALD A. TATTON.

F. J. WILLIS,
Secretary,

7*th August*, 1908.

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ROYAL COMMISSION ON SEWAGE DISPOSAL.

FIFTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

Methods of Treating and Disposing of Sewage.

APPENDIX I.

MINUTES OF EVIDENCE.

Presented to both Houses of Parliament by Command of His Majesty.



LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
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1908.

[Cd. 4279.] *Price* 9*s.* 7*d.*



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October 1908

MINUTES OF EVIDENCE

TAKEN BEFORE THE

ROYAL COMMISSION

APPOINTED TO

Inquire and Report: First, what method or methods of treating and disposing of Sewage (including any Liquid from any Factory, or Manufacturing Process) may properly be adopted consistently with due regard for the requirements of the existing Law, for the protection of Public Health, and for the economical and efficient discharge of the duties of Local Authorities; and if more than one method may be so adopted, by what rules, in relation to the nature or volume of Sewage, or the Population to be served, or other varying circumstances or requirements, should the particular Method of Treatment and Disposal to be adopted, be determined; and, secondly, to make any Recommendations which may be deemed desirable with reference to the Treatment and Disposal of Sewage.

SIXTY-EIGHTH DAY.

Tuesday, 16*th February*, 1904.

PRESENT:

Colonel T. W. HARDING, J.P. (*in the Chair*).

Sir MICHAEL FOSTER, K.C.B., F.R.S., M.P.
Sir WILLIAM RAMSAY, K.C.B., F.R.S.
Mr. W. H. POWER, C.B., F.R.S.
Major-General CONSTANTINE PHIPPS CAREY, C.B., R.E.

Mr. F. J. WILLIS, *Secretary*.

DR. COWIE, called; and Examined.

19728. (*Chairman.*) Dr. Cowie, we had the pleasure of seeing you when we were in Scotland. Would you be good enough, therefore, to act as introducer of the gentlemen about you? I understand we have before us the Provost of Rothes?—(*Dr. Cowie.*) No, he is not here, sir.

19729. Then would you tell us who these gentlemen are?—(*Dr. Cowie.*) Mr. Allan, Mr. Thorne, Mr. Hopkins, Mr. James Robertson, Mr. Doig, Mr. Grant Glen Grant, Mr. Fergusson (Jura), Mr. Brown (Campbeltown), Mr. Mustard.

19730. Are all these gentlemen interested in distilleries?—Every one of them.

19731. And is this deputation representative of some association—if so, what?—It represents the whole Scotch malt distilling trade.

19732. What is the name of the association?—Well, we will take it this way: There are here representatives from the South, East, and West of Scotland Malt Distillers' Association, as well as from the North of Scotland Malt Distillers' Association, to which I belong.

19733. Then this is a combination of associations?—That is so.

19734. And I understand that you come before us in consequence of the difficulty which lies before distillers owing to decisions which have been given by the Court of Session in actions at the instance of John Ritchie Findlay *v.* Dailuaine-Talisker Distillery Co., Limited, and Dailuaine-Talisker Distillery Co. *v.* James W. H. Grant, the particulars of which you have put before us?—That is so.

19735. I understand that Dr. Cowie, on behalf of the deputation to-day, has a statement to make to the Commission?—That is so.

19736. Will Dr. Cowie be good enough to proceed?—Colonel Harding and gentlemen, the deputation that I have the honour to introduce to you to-day represents practically all the distillery interests in Scotland. During the year 1902 the output from these distilleries was over 29,000,000 gallons, representing about £15,000,000 sterling in Imperial revenue per annum. There are 167 such works in Scotland. My interest, as you know, is more particularly connected with the North of Scotland, and you will see from the map which has been put in that a great number of these works are concentrated round the Spey Valley. The gentlemen who are here to-day, however, represent Islay and Campbelltown, the south, the west, and the east—practically all the malt distillers of Scotland. Although the question has been more acute in our district, it is being raised all over the country. The industry which we represent, as you are aware, employs a large number of workmen, both directly and indirectly. It affords an outlet for barley and other agricultural products of the neighbourhoods where the distilleries are situated, and also gives cheap cattle food, without which, during the last two years, I may say, in our part of the country, the farmers in some of our Highland glens would have been reduced to dire extremity. As it is, we know they have had very bad crops for two years, no root crop, and their white crop has failed, and they have had to depend for food for their cattle on what they have got from the distilleries. Farmers have been coming to my place, five, six, or seven miles, to drive away food for their cattle. I am not able to give you figures regarding the amount of capital invested in this industry, but it is enormous. For some years past the question of the disposal of waste products from the distilleries has been a burning one between the distiller and riparian proprietors. Into the composition of these by-products it is unnecessary for me to enter, as the Commission has already investigated this on their own account. But it is necessary for me to touch upon the difficulty and the gravity of the problem. I may remind you that during your visit to the north last May, we were able to show you varied and extensive works for the purification of these bye-products, and I think we were able to convince you at that time that we were making earnest and every possible endeavour conscientiously to grapple with this problem. I think you were also told that the distillers on the Spey offered to construct a pipe to the sea at a cost of from £40,000 to £50,000, but that

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the proprietor of the fishings at the mouth of the river, the Duke of Richmond and Gordon, objected to this proposal. We also, as you know, offered a premium for an efficient system for the disposal of our sewage, but nothing came of it. I must say that perhaps at one time the distillers, like other manufacturers, when this problem confronted them, were a little slow to move till they saw how things would go, but I have to impress on the Commission that I am certain every distiller is now anxious to find some way out of this trouble and to meet the complaints that have been made against them by the proprietors. As you have said, sir, it is owing to the judgments of the Court of Session against this distillery company and others that are now pending in the court (because this is not an individual instance, but it is a string of a number of cases that are instituted against distillers), the distillery industry has become thoroughly alarmed, and they quite see that it is only a matter of time when this large and important industry will be absolutely shut up unless something can be done to remedy the trouble. We have come to you to-day to ask you to send your experts to investigate and see what can be done, with the view to fixing some standard of purity up to which it would be safe for the riparian proprietors to receive effluents from distilleries into the stream; also to investigate the methods which you saw working, such as evaporation, incineration, and destruction works, which are now in danger of being interdicted on account of the smell arising from the burning of the pot-ale, and also to report on what you would consider the best and most efficient means of solving the question. If, unfortunately, as we are led to understand, your staff is fully occupied at the present moment observing works with a view to a further report on sewage effluents, and sewage and trade effluents mixed, so that you cannot at once investigate the methods available for dealing with distillery refuse, we would offer the suggestion that you should ask the principal proprietors on the Spey to come before you and give their views, and see if a *modus vivendi* between the distillers and the proprietors could not be arrived at until such time as you are able to investigate and report upon the standard of purity which would be reasonable to all concerned. I may say that on every occasion upon which we have asked the riparian owners for some indication as to what will satisfy them they have invariably said, "We just want pure water, and we do not care how you arrive at this." That in our opinion is practically impossible—is an absolute impossibility. There is another point which I should like to bring before the attention of the Commission. I think it struck you when you came up last spring that sufficient land was probably not employed in many cases in works for purification. Well, a good many distillers—in fact, all distillers—have what they call feus—that is, a freehold for which they pay a large annual rent. When land was required for purification works, these gentlemen from whom we had the feus either asked an exorbitant annual feu duty or refused the land altogether, although at the same time they are receiving large annual payments for the land occupied by the distillery. This is actually the case now at Rothes, as Mr. Grant and Mr. Robertson will tell you. They threaten us with an action for interdict, and then demand £15 to £30 an acre per annum for land which is not worth as many shillings from an agricultural point of view. We would ask you, therefore, gentlemen, if you could possibly see your way to promote legislation by which on application to the County Council or some other local authority it might be possible for distillers and other manufacturers (for the same thing obtains with regard to some other industries in the north) to obtain land at a reasonable price, so that our industries might not be hampered in that way. As I have said before, perhaps we were a little backward at one time in doing what we could to solve this problem, but for the last few years large sums have been spent, and everybody has been doing his very best to arrive at the solution. We would welcome such a proposal as is made in your third report on sewage disposal for England, that some such central authority should be appointed as you propose, to deal with the matter between the manufacturers and local authorities or proprietors. Such a central authority as you recommend would be a far better tribunal than the ordinary courts. We would pray that you would recommend that this should also be extended to Scotland. At present we, as individuals, are spending large sums without any security that the works that are being erected are the best possible available. This could be obviated if your recommendations were accepted, and it would save a great deal of money both to the country and to individuals at large. The landlords, no doubt, are as anxious as we are that money should not be needlessly wasted on works and on useless litigation. If a central authority were appointed, there is no doubt that this would be sufficient to safeguard the interests of all parties. Before drawing my remarks to a conclusion, I would like to say a few words with regard to the fishing rights of the riparian owners on the Spey, and Mr. Grant, who is an old fisherman on the Spey, and who has large experience, will speak to this later. For the last four years we maintain that the damage to fishing has been infinitesimal, if not *nil*, on the Spey, and this is evidenced by the report of the river watchers of the number of fish on the spawning beds during the last two or three seasons; also, indeed, by reports in the newspapers. Since the opening of the fishing season on the Spey on the 11th February last the fishing has been a record one, both from the point of view of the rod fisherman and the netsman. They have, I think, made absolute records in rod fishing, from what I hear. I wish to impress upon the Commission that we distillers do not want in any way to injure the streams or to encroach on the rights of the riparian owners; we only ask reasonable facilities for carrying on our business, and we are in hopes that an interview between you and the riparian owners will bring into proper perspective our respective positions, and convince them that their interests are not being unduly encroached upon by us, and that there must be a little give and take between us before a settlement can be effected. In what I have said with regard to the Spey—you have been hearing so much about it—I have spoken from my own point of view; the other gentlemen can speak for theirs, but I may say the question is acute all over Scotland, and they will be able to tell you so. Well, there are four points that we wish to urge upon you. First, that you may send your scientific staff up to investigate the methods in operation, and to give an opinion as to what is the best possible means of purification of our effluents and to establish some standard of purity. Second, that you urge upon the Government to promote legislation whereby application to a local authority manufacturers may compulsorily obtain land for purification works at a reasonable figure. Third, that you extend the recommendations in your third report to Scotland, so that the interests of the manufacturers as well as those of the landlords may be safeguarded by the appointment of a central authority. Fourth, we venture to suggest that you ask the Duke of Richmond and Gordon, Mr. Menzies of Arndilly, Mr. Findlay of Aberlour, and Mr. Grant of Elchies, and other proprietors to exchange views with you in order that some arrangement may be arrived at until such time as you can report.

19737. Does any other member of the deputation wish to address the Commission?—(*Mr. Grant.*) I have got very little to say, sir. The only thing I should say after the exhaustive statement that Dr. Cowie has given you—the only point I wish to talk about is entirely from a fisher's point of view. I have fished the Spey for 46 years steadily every year, and in my opinion the effluents that are going into the river do not in any way hinder sport—not in the slightest. I have had experience; my father had the fishing below where this Dailuaine Distillery is for 21 years; I fished it during his lifetime, and I had it for five years myself immediately below where the Dailuaine Distillery effluents were going into the river. I have seen the burnt ale coming into the top pool, and it ran down the side, but in the second pool the water ran to the side, and consequently the whole of that pool the burnt ale was distributed right over it, and I have killed many and many a hundred salmon in that pool when that effluent has been going down.

19738. Do you suggest to us that pot-ale is an excellent thing for improving the condition of the river for fisheries?—I do not say that it is an excellent thing for improving the condition of the river, but it does not hinder sport. That is my own personal experience after 46 years.

19739. (*Sir Michael Foster.*) Not only now does it not injure sport, but it has not done so in past years?—Certainly not.

19740. When your proportion was not so good as it is at present?—Certainly not.

19741. (*Major-General Carey.*) On the other hand, you had not got the distilleries four years ago on the Spey, really?—I had; you see, I am both a distiller and a fisherman.

19742. (*Mr. Power.*) What proportion does the effluent from the distilleries bear to the total water in the river at the point you are mentioning?—Oh, infinitesimal.

19743. Infinitesimal as compared with the water in the river?—Oh, certainly. The Spey is a very rapid river, and carries away everything. The pot-ale would simply go down the side, I fancy; probably a matter of 10ft. or 12ft. would be where the pot-ale would come down into the river, and it would remain there unless the body of the river was striking against some other projection so as to mix it all up. Really the pot ale goes down the side.

19744. (*Sir William Ramsay.*) Does it not froth?—Yes.

19744*. Does not that prevent you seeing your cast?—Certainly not.

19745. (*Sir Michael Foster.*) Are your views shared by all fishermen who are fishing in the district—those who are not distillers, simply fishermen?—The fact of the matter is this—that owing to the exhaustive net fishing, salmon have become very scarce. If you do not allow fish up to breed you cannot get fish. In my young days I have seen hundreds and hundreds of fish spawning, and now you will walk miles and not see a pair of spawning fish on the places where there used to be hundreds. For the last 10 years I have had the shooting of Glen Livet, where the Avon, the Livet, and all these streams which are admirably adapted for spawning fish are. While in my young days hundreds of fish were there, you will go and you will walk for a couple of hours without seeing a pair of spawning fish now, simply because thebrood of the fish are killed out by over-netting, so much so that the Duke of Richmond this year has taken off 7½ miles of nets.

19746. (*Chairman.*) It occurs to me, Mr. Grant, that it is scarcely worth while to press that, is it, because I think you yourself would not deny that pot-ale is in itself an evil in that beautiful stream; only you suggest to us that its volume is relatively so small to that of the stream itself that the damage that it may do is not very serious?—It is not serious.

19747. But I think you would probably agree that damage of a sort there is. You cannot suggest that pot-ale is good for the stream in regard to the fisheries?—It does not prevent fish-taking, and it does not kill fish.

19748. I think we need not press that further, because you suggest to the Commission, which is possibly true, that the reduction in the number of fish may be due to other causes altogether than anything in connection with distilling?—Certainly.

19749. And, on the other hand, Dr. Cowie told us just now that the recent condition of the fisheries has been very good. I think he spoke about a record rod-fishing in the Spey, so that I think it is unnecessary to press that further. Do you wish to say anything to the Commission in regard to your own experience—for instance, as to the best way of dealing with the effluents from distilleries?—After what Dr. Cowie has said I can add nothing.

19750. Well, I will not press you for any further information on the question of the fisheries. Does any other member of the deputation wish to add anything to what has been said by Dr. Cowie?—(*Mr. Fergusson.*) I represent the South, and am the Chairman of the South, West, and East of Scotland Malt Distillers' Association. I have been sent here because we wish, along with the other deputies here, to represent the whole distilling industry of Scotland. I may say that in our Association this matter of bye-products does not affect us. Our distilleries are for the most part situated on the seaboard, and we get access to the sea for our refuse. We have some distilleries in the country, and we do not know the moment that we might require to join with the rest in getting some decision arrived at about the impurity adopted in rivers. I would only back up what Dr. Cowie has said on this—that malt distilling is the principal industry of the north of Scotland, and that it provides wages and employment to a great number of places which otherwise would be in abject poverty. Scotch whiskey is becoming a very important stimulant. It is the most popular at the present moment of all stimulants, and it is supposed to be the most wholesome. As these distillers are making the very best malt whiskey, they think it is rather hard that they should not be allowed to carry on the work without unnecessary obstruction. Dr. Cowie has said that they have no wish to adulterate the rivers; they will do everything science can suggest to make their effluents innocuous; but there seems to be something that will not precipitate and they cannot get quit of, and technically it is an adulteration. Well, I suppose they wish some latitude in that respect. I only wish to say, Mr. Chairman and Commissioners, that in our Association we sympathise very much with the difficulty of our brethren in the north, and we would be very glad if some scientific basis could be arrived at which would prevent unnecessary litigation.

19751. Mr. Fergusson, I gather from your observations that the distilleries in Scotland are centred mainly in three districts—on the Forth, the Clyde, and the Spey?—On the Clyde—that is Campbelltown, of course.

19752. And in regard to the Forth and the Clyde—those being large sea arms or tidal streams, the difficulty is not acute there, and therefore the Commission may for the present concentrate their attention upon the acute difficulties on the Spey?—That is so.

19753. There is on that stream quite a large concentration of distilleries?—Yes.

19754. I see on the map a great number of red spots in that district?—Quite so.

19755. And there is also a very beautiful stream which has great fishing value?—Yes.

19756. And therefore really that is an acute spot which we must direct attention to?—That is so.

19757. Now, Dr. Cowie, you have referred to the work which has already been done which some of the Commissioners had the advantage of seeing when they visited Scotland last year. We should be interested in knowing to what extent progress has been made since then. I gather, in the first instance, distillers, like most other manufacturers, were by no means keen to purify their trade effluents; they possibly allowed the matter to drift on too long until the condition became extremely acute. That may be to some extent the cause of their present difficulty, but we did see when we were there several honest attempts at dealing with this difficulty, and those were mainly in three directions. One was in the direction of purification by means of successive passages over contact beds—as many, if I remember right, as eight in one case?—(*Dr. Cowie.*) Yes.

19758. Another direction was the evaporation of the pot-ale which was kept separate from other effluents, which may be less difficult to deal with?—Yes.

19759. And finally, in one case we saw the mixture of the distillery effluent with the domestic sewage, which was attempted to be dealt with by the municipality at Rothes. Well, I cannot say that we were struck with the great success in any of these cases, with the results obtained, except in connection with evaporation where clearly the success was complete, inasmuch as the effluent disappeared altogether, and in one particular case—I think it was the case of the Glendullan Distillery—we found there also that the effluent disappeared altogether, because after being dealt with upon contact beds the filtrate from the beds was pumped to a plateau on the top of a hill, and there distributed over a large area of land, so that none has reached the stream at all?—That was at Coleburn Distillery.

19760. Was that Coleburn Distillery; I dare say you are right there?—At Glendullan they evaporate simply.

19761. That was so; it was at the Coleburn Distillery that they pumped to the top of a hill; and, therefore, there was no effluent; and, therefore, the result was absolute perfection. You cannot get beyond that. In the cases where you had evaporation there also the effluent disappeared; but the whole difficulty then arose in connection with the residual matters, either syrup in the case where there was only partial evaporation, or a manurial ash which was produced where there was complete burning?—Yes.

19762. Now you have spoken to us about the objection which has arisen in connection with the burning; an objection in connection with bad smells arising from the burning?—Yes.

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19763. Now are you able briefly to inform the Commission what progress, if any, has been made in these three directions since the Commission visited Scotland last year? For instance, in your own distillery we saw a very complete arrangement of contact beds—I think seven at one time?—Seven.

19764. You were proposing to put an eighth?—Yes.

19765. And you obtained results which were a very obvious improvement on the original effluent that went to the beds, but a result which I think you also thought was scarcely good enough to be turned into the stream. You were proposing then to make some further experiments; possibly you may have something to say to us in regard to them. These matters would guide the Commission somewhat in the decision they will have to come to?—In the autumn I went to see some purification works with Mr. Frye and Mr. Willis, and as the result I put up a continuous filter, which has materially improved the effluent.

19766. At your own works?—At my own works, yes.

19767. With what previous treatment?—First passing it through a sludging compartment, then over a bed consisting of limestone, after this ponding it in seven contact beds, and passing it over a Whitaker Tower. This is our present treatment, and it is giving excellent results. We tried continuous filtration in the contact beds, with tipping spouts, but it did not answer in my case. We had great difficulty with the distributor on the continuous filter; it silted up, and did not work. The local plumber has invented a very efficient distributor; it consists of a circular copper plate, which is perforated; on this plate are soldered, radiating from the centre, perpendicular strips of copper; on this two jets of effluent are made to impinge, which results in a uniform spray being distributed over the filter by the rotation of the plate. The plate is about 4ft. above the surface of the bed. I think this distributor would be useful for sewage as well as for distillery effluent. We have found that the trouble in our contact beds has arisen from yeast cells propagating when the lactic acid in the pot-ale has become considerably neutralised; this takes place in from two to three contacts, and, as a rule, in the fifth or sixth contact we have a neutral effluent. I may tell the Commission that experiments are at present being carried out in the cultivation of yeast in treated pot-ale on these lines, and, I believe, with considerable success, but they are not sufficiently advanced for me to say anything about them.

19768. (*Sir Michael Foster.*) Do you mean with the view to propagate yeast?—To propagate yeast.

19769. Simply for the propagation of the yeast or with regard to fermentation?—To get yeast we must have fermentation.

19770. Not for the carrying on of fermentation, simply to get a sort of yeast?—The saccharometer shows about 25 to 30 per cent. of spirit more than is obtained by distillation; there must, therefore, be a certain amount of spirit in pot-ale in some form; this we rely upon for the propagation of the yeast.

19771. Is there any fermentable substance left in the pot-ale; any large amount?—Nothing has been found so far to deal with it. Then we have also adopted another system—Dr. Hunter's system. He boils the pot-ale with lime, and then adds the acid phosphate of lime, which produces a clear effluent and a flocculent precipitate, which goes rapidly to the bottom.

19772. (*Chairman.*) We are anxious quite to understand that. Did I understand, Dr. Cowie, in regard to your earlier observations as to the changes which have been carried on at your works since we visited them that you have been adding to the eight contacts a percolating bed?—Yes.

19773. And did I gather further that you found no great advantage after four contacts, because then evils began to arise?—No, sir; I stated that the yeast formed.

19774. Yes, but you obtained alkalinity after four contacts?—After five or six contacts.

19775. Then is it suggested that if for the last four contacts you substitute percolating beds possibly some advantage would arise?—We tried that at my distillery.

19776. And with what result?—The result was not satisfactory at my distillery, but at Dailuaine Distillery they are getting an excellent effluent by continuous filtration.

19777. (*Mr. Power.*) Without any contact previously?—Without any contact previously.

19778. (*Chairman.*) In that case you have some sort of settlement by lime or otherwise?—There is no settlement; they are to adopt this settlement by lime.

19779. In the case you referred to in answer to Mr. Power just now, is there simply the passage of the crude liquor upon the percolating bed?—Upon the percolating bed, yes.

19780. And the results are better than contact beds?—They are there; but I do not find it so in my beds.

19781. In that particular instance fair results have been obtained?—A better result has been obtained.

19782. What kind of a result; was there absence of acidity?—Oh, absolute absence of acidity.

19783. You get a neutral effluent?—A neutral effluent.

19784. And with what reduction of impurities?—(*Mr. Mustard.*) That is a most extraordinary thing; we cannot explain it.

19785. The secretary says you cannot explain it. I would like to know whether Dr. Cowie can say why it has succeeded in that particular case, and not in his own. Is there anything very different in the character of the liquid being dealt with?—(*Dr. Cowie.*) I think the liquor they were using was very much more dilute than the liquor I was passing over my beds; I think that is the secret of their success.

19786. Do you think that dilution would considerably assist the filtration?—I am satisfied that is so, and we are diluting more now.

19787. (*Sir Michael Foster.*) And getting better results?—Better results; yes.

19788. You do not get the growth of the yeast in your percolating beds?—Not so much the growth of the yeast; we have got the sludging tank, which takes it out a good deal. This process of boiling with lime will absolutely destroy all the yeast cells.

19789. (*Chairman.*) That is rather an interesting direction for us to inquire into. The first process of treatment by lime or some other chemical matter has been carried out on a practical scale at your works?—No, at Mr. Thorne's works at Aberlour.

19790. Can he, or will you, give us any data in regard to the results obtained?—He will be able to speak to it, I expect.

19791. Can you, sir, give us the results which have been obtained by first a process of chemical treatment and sedimentation, followed by a process of filtration?—(*Mr. Thorne.*) I have our architect here; unfortunately the director of our company, who has looked after Aberlour, has just died, and although I am chairman I am not so well up in these matters as he was. Our architect, Mr. Doig, happens to be here; I am sure he will be very glad to give the information required at once.

19792. Can you give us the results which have been obtained in that experiment?—(*Mr. Doig.*) I cannot give you an analysis,

19793. Tell us what the experiment is?—The experiment is, first, you boil the pot-ale, and likewise the washings from the tun-room—the yeast washings—and on boiling you add a certain proportion of lime.

19794. (*Sir William Ramsay.*) To the boiling liquor?—To the boiling liquor.

19795. (*Chairman.*) You do not mean boiling with a view to evaporation, simply with a view to heating?—Yes, simply with regard to heating, and afterwards you add a little superphosphate. Then, of course, it deposits very quickly. Then, in about a quarter of an hour, you will have a complete deposit. Then the sludge is taken away, and the supernatant liquor run off and mixed with the steep water washings, and other effluents, and put through a series of contact beds—seven contact beds—six of clinker and one of sand.

19796. With what result?—Well the effluent is very good. (*Dr. Cowie.*) This process, Colonel Harding, has only been going about a couple of months. (*Mr. Doig.*) About a couple of months. (*Mr. Mustard.*) Hardly so much—since January, about the middle of January, so that it really has not, so far, had a long enough trial to enable us to speak very distinctly about it, but we will send you the results.

19797. Does your experience go to show, with regard to the treatment of waste from the distilleries, that it is probably advantageous to first of all treat it in some way with a view to sedimentation?—(*Dr. Cowie.*) That is my opinion.

19798. And then to deal with it over fewer contacts than have hitherto been attempted, or by percolating filters?—I would be inclined to do fewer contacts now from my experience, and put on a percolating filter in the end—a good big percolating filter, I think.

19799. Then are you of opinion that progress is being made in connection with the treatment of these waste liquors by those means?—I am satisfied that that is so.

19800. Are you able to tell us now in regard to the process of evaporation that we then saw? It was suggested to us then that these processes, which, of course, inasmuch as they evaporated the effluents, were perfectly effective from the polluting point of view?—Quite.

19800-1. That these would be successful if it were possible to dispose of the residual matters, the syrup, or the ash. Can you tell us anything further as to whether the hopes that were held out to us in regard to the sale of these by-products have been fulfilled?—You remember seeing, the last works you saw, where they were making the cattle food; that company is now in liquidation.

19802. And what about the Glendullan?—I understand they have considerable difficulty in getting rid of their syrup. There is no outlet for it. I see it lying there in large quantities.

19803. With regard to the ash?—With regard to the ash, Mr. Robertson is here; he will speak of it himself.

19804. What success have you had in disposing of the ash which was produced by the complete drying up of the syrup?—(*Mr. Robertson.*) Well, Mr. Chairman, we had some difficulty; in fact, we still have; but it is a new thing, and it is very difficult to get the manure trade to take it on and look at it, although they are satisfied that there is a beneficial analysis. What we are always met with is the remark, "Well, analysis is not practice." And, of course, we expect to be able to make something out of this, to get some return; but the expense, so far as we have found, of working this evaporating plant will, I think, be prohibitive for the small distillery to undertake it, unless we can show something better than we are now in our return.

19805. (*Sir Michael Foster.*) What is the main composition of your ash produce? What are the striking constituents?—Potash; there is about 5 to 6 per cent. I think about 7 to 8 per cent. of ammonia, and a certain amount of phosphate.

19806. How much phosphate?—From 15 to 16 per cent. phosphate.

19807. A large amount!—Well, we were told by the expert that analysed that it is very good, but when you go to sell the by-product—well, to make a market is the difficulty. We may be able to do that in time, but, as we are only producing a very small quantity at one distillery, it is not large enough to make a trade, if I may say.

19808. (*Chairman.*) You are in the midst of an agricultural district?—Yes.

19809. You say you have not been able to persuade the agriculturists in your district to take this?—Well, we do not get what we consider the full value for it you see; that is our difficulty just now.

19810. You can get a price for it?—Yes, £5 to £6 per ton.

19811. But not a sufficiently high price to make a profit?—I do not say, even though we got the analytical value of it, we would make a profit.

19812. We may take it the amount of this ash is so small there would be no difficulty in getting rid of it at a price, or getting rid of it without selling?—Oh, we could get rid of it. It is not "ash," but dried residue.

19813. And the whole question of cost would turn on the cost of the process itself?—Yes.

19814. Is the process very expensive?—Yes.

19815. You suggest that it is?—Yes, I do, and, knowing what I know about distilling, if a distillery had to go into this process that we have at Tamdhu just now, he would want, what I think Dr. Cowie has emphasised so much in his statement, and which I thoroughly endorse myself, some assurance if he spends £4,000, and, perhaps, on a big distillery like Dailuaine, it would mean a great deal more, if he went in for that sort of thing; he would want some assurance that he was not going to be pulled up over smell through the chimney. We have been hampered in that way.

19816. Well, tell us what your difficulty has been in that respect; have you been pulled up; has any interdict been sought against you?—Oh, no; we have not got that length yet, but we are threatened.

19817. What is the nature of the complaint that has been made?—That we are polluting the air by the smell in drying this residue.

19818. Does it pass into a chimney?—It goes up the ordinary chimney stack.

19819. What is the height of it?—140ft.

19820. And is it alleged that this may be smelt in the neighbourhood?—Oh, yes, it is the complaint of the tenant of one of the fishings on the River Spey that when the wind is in that direction it blows towards his house. That is the complaint made by the Laird which he received from his tenant.

19821. (*Sir Michael Foster.*) Is it in the drying?—It is not in the evaporation, of course, but in the burning We have tried to obviate the burning as much as possible by reducing the heat in the flues. We found that the heat was so great that we were burning it, and if we were burning it we lost so much of the valuable nitrogenuous constituents in the result at the end of the week, and we also made the smell, which, I admit, is objectionable altogether. It is a pretty strong smell, and why it is objectionable I cannot tell you. I do not know anything about the analytical part of it at all. I know that there are certain acids driven off by this heat.

19822. Have you tried various methods of heating and drying, or only one?—What we want to do is to make use of the waste heat from the boiler furnace. Unless we do that there is no advantage. If we cannot use the waste heat, then the process is absolutely no use, because we require so many tons of coal now a week; unless we make use of the waste heat it would take a coal pit. (*Dr. Cowie.*) It would be as well that the Commission should know that coal costs £1 a ton in our district. (*Mr. Robertson.*) Yes, just about that just now.

19823. (*Chairman.*) You have a great deal of waste heat, which you claim you can utilise in drying this?—Oh, yes; the difficulty in taking the waste heat along the flue is to avoid burning this syrup when it is being dried.

19824. You think, then, that the slower drying of the syrup would be better?—Yes.

19825. You are not without hope of being able to accomplish that by experience?—No, I am not, so far as we are concerned.

19826. Then, as regards your process, you have reached this stage that you have ceased to pollute the Spey altogether?—Yes, so far as regards burnt ale.

19827. So far as fishing rights are concerned, nobody can make a complaint of you at all?—I do not know about that. At the last interview we had on this question at the distillery, the remark of one of the riparian proprietors to me was, "Well, you have got on so far, but you have always got the steep water and the washings and the spent lees to deal with, and you will have to deal with these some day." Well, we claim that there is no pollution by these other effluents.

19828. I understand there are two sides to this question; one is the question of the pot-ale, and in that particular case you do away with the effluents and reduce pot-ale to absolute ash; and in regard to the other branch of the work, what are you doing? You suggest that these effluents are not polluting, but probably there is a difference of opinion upon that?—Yes.

19829. But probably those effluents would not offer any insuperable difficulty, would they?—No.

19830. They are very much easier to deal with?—We throw them on the waste ground that we have now; we pump them on; we have to pump them across the railway on to this waste ground, and we let them find their way.

19831. It percolates into the neighbouring ground?—Yes; we have had no complaint of that as yet.

19832. You anticipate that ultimately the effluents will appear in the stream?—No, I do not think so; I do not think it would pollute.

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19833. By evaporation you get rid of it?—We could never evaporate these other effluents ; the dissolved ingredients of these matters are so small, as compared to burnt ale ; the polluting value is so small.

19834. At the present moment the result of this percolation, so far as the stream is concerned, is nil ; it does not reach the stream?—It, perhaps, has not had time to come through.

19835. You foresee that it may come through?—Yes, it may appear. We are told by the experts that if we dilute these enough they will never pollute.

19836. Do you suggest that the natural dilution of the stream is the only cure?—That we ought to be allowed to put them into the stream ; our Laird asks us not to do it ; therefore we put it on to the waste ground.

19837. (*Sir William Ramsay.*) Deprived of all the obnoxious ingredients, it may go into the stream relieved of these?—It may.

19838. (*Chairman.*) You think it may reach the stream ultimately, but you think it will be in a safely purified condition?—Yes.

19839. That is what you want us to understand?—In fact, not only so, if we were allowed to dilute that properly and put it into the stream it would not do any harm.

19840. Of the two classes of effluents, clearly the pot-ale is the difficulty ; the other is a minor difficulty which can be met in various ways?—Yes, that is our own opinion, and that is why we went in for evaporation, whereas the others are experimenting—and we are simply experimenting, too, for that matter, because it is a loss from year to year, and a serious one. (*Mr. Mustard.*) It is an establishment involving an expenditure of many thousands of pounds.

19841. I want to ask Dr. Cowie a question or two. You told us just now that the deputation represented the distillers of Scotland, and you spoke to us of the vast capital that was involved in that industry. Has any attempt been made by these associations as such to deal with this question ; has this rich body of distillers engaged any experts to study this matter for them, and to carry out experiments for them?—(*Dr. Cowie.*) Yes, we have engaged experts and paid large fees—several large fees.

19842. Where are the experiments being carried out? Are experiments being carried out at the cost of the association?—Not at the cost of the association. (*Mr. Mustard.*) Oh, dear me, Dr. Cowie, we have paid sums of money over and over again through the association.

19843. For the purpose of carrying out experiments? —Experiments without any result whatever ; do not disguise the thing.

19844. Your secretary says that the experiments which have been made, I understand, at the expense of the association have resulted——?—In nothing.

19845. In showing that nothing can be done?—That is so. (*Dr. Cowie.*) That is so.

19846. But do you suggest to the Commission that that is the result of the experiments which, either on behalf of these distillers as an association or on behalf of individual distillers, have been carried on, that they have given no better results?—That is so.

19847. That there is no hope whatever of dealing with this matter?—I do not say no hope

19848. (*Sir Michael Foster.*) Then do you think we can deal with it ; do you think that our experts can do what your experts have failed to do?—Well, we think we can get a good deal of guidance from you.

19849. But surely we are misunderstanding each other, are we not?—We must be, I think.

19850. (*Chairman.*) You said some of the experiments you had undertaken were rather promising?—Yes.

19851. Your secretary tells us that all these experiments which have been carried out on behalf of these associations have been utter failures?—(*Mr. Mustard.*) That is so, Mr. Chairman ; on behalf of the association, but Dr. Cowie told you outside the association.

19852. We are to understand that whereas the association experiments have failed, individual experiments in certain cases have proved hopeful?—Exactly. What Dr. Cowie told you about was not an association experiment.

19853. Then I return to the question of the association ; as it appears to us—or to me, I do not speak for my colleagues in this matter—it does appear to me that where you have an exceedingly powerful organisation of this kind, and where you have a difficulty to deal with, which is at once very great, and which you all keenly appreciate, that clearly some attempt ought to be made by the distillers as a body to endeavour to solve this difficulty for the benefit of the individual distillers ; has nothing been done?—(*Dr. Cowie.*) Well, all those works are being put up and worked, you know.

19854. But are they worked at the expense of the individual distiller?—At the expense of the individual distiller ; but we have had advice from eminent chemists, to whom large sums have been paid by the association as an association.

19855. The suggestion, I gather, is rather that this Commission should employ its experts to find out for the Distilleries' Association what is the best way of dealing with these matters?—Well, the suggestion that we have come here to make is that we should get an official pronouncement of what is the best possible means of dealing with our works ; that you should make these observations on the same lines as you are at present doing at the various stations in England. I understand that at present you have certain places under observation in England.

19856. Yes, just as we have under observation the various experiments that you are carrying out on the Spey?—Yes.

19857. But I am afraid this Commission cannot recognise as part of its direct business that they shall tell the distillers the best way of carrying on their business. We are prepared to investigate these processes, and to see which of them show advantages and which do not, and to express an opinion at the close of our investigations ; what I think I feel in the matter is that the main business lies with the distillers themselves to find out a solution of their difficulty. Any assistance that this Commission can give them they will readily give, but the main business must be carried out by the distillers themselves?—We are carrying on these experiments at present. There are several new processes being tried since your last visit. Mr. Russell Duncan has a plant at Craigellachie Distillery ; there is also an oxi-chloride process being tried.

19858. (*Sir Michael Foster.*) At the instance of the individual distillers?—At the instance of the individual distillers.

19859. I rather conclude from what you have said that the money which the association has spent has been rather the payment of fees for advice to eminent chemists than for direct experiments in this case?—That is so.

19860. What Colonel Harding was inquiring was whether these associations had not carried on experimental investigations of the kind that you are asking us to do?—Well, I only wanted you to come up and observe and see, and report on what we were doing. We do not come here asking you to make experiments for us ; and if your experts suggested any experiments every distiller would be only too willing to carry them out at his own expense. We do not ask you to do anything of that sort ; we simply come here asking for advice and guidance.

19861. (*Chairman.*) I think we gather then, generally, from the information that has been put before us, that the distillers are now perfectly aware that they must make an attempt to reduce the pollution, that they are making serious attempts in various directions, some of which are at present fairly hopeful ; apparently, they think a certain time must be given to them to carry out these experiments ; is that the position?—That is the position.

19862. (*Sir William Ramsay.*) I understand Dr. McGowan has been corresponding with you?—Yes.

19863. And he has been producing a perfectly good effluent by liming the pot-ale and filtering it?—Yes.

19864. Could that not be tried on a large scale to see if it will work as admirably as in the experiment?—That is being tried.

19865. By yourself?—No. Well it is practically the same thing at Aberlour. After the pot-ale is boiled with lime till it is faintly alkaline, then the superphosphate of lime is added till it is faintly acid.

19866. It does not boil?—It is discharged from the still at nearly boiling point. If you try the experiment

with pot-ale you will find it comes down much more rapidly, and that the precipitate is much heavier than that produced by adding the milk of lime alone.

19867. It is costly to boil it; it runs out hot?—It only requires a little steam to boil it. It is discharged from the still at a temperature of about 190 deg. to 195 deg. Fahr.

19868. You would not let it cool?—Simply pump it direct into the precipitating tank, add ground lime to faint alkalinity, and then neutralise with phosphate of lime.

19869. Phosphate and boil?—Yes.

19870. Would it not be possible to get that plan adopted all round, because it is an obvious one?—Well, we want a little time to see how these things would do. That is the view of the gentlemen here; as it is, we are being forced at the present time, and we have got to an *impasse*.

19871. Speaking on that subject, the judgment of the Court appeared to be that you had had a considerable amount of time to look round you; the judgment was based on the fact, was it not, that you had had four or five years?—Well, that is so, I believe.

19872. (*Major-General Carey.*) Practically nothing had been done?—In that particular case. The other cases in which they are being attacked; for instance, in this case Mr. Robertson has told you about, they have spent £12,500 in this evaporator process experimenting; now they are likely to be shut up, because they are polluting the air. We do not know what to do.

19873. (*Mr. Power.*) Have the associations employed experts to pronounce on the relative value of the experiments the various distillers have carried out, or is each one left to experiment himself, and judge of the value of the effluent himself?—Experts have been sent down by the Court in various cases, and we have seen their reports to the Court.

19874. To see whether or not they satisfied certain conditions?—Yes.

19875. (*Sir William Ramsay.*) They do not give you any advice what to do?—The great trouble is, we cannot get any indication from the riparian proprietors as to what they will be satisfied with. They say, "We want you to put back pure water into the stream," and anything short of that they will not accept.

19876. (*Sir Michael Foster.*) Do I understand, Dr. Cowie, that either as individual distillers, or by means of the Association of Distillers, you are prepared still to carry on experimental investigations, with the view to seeing if your processes can be improved?—Most certainly.

19877. You are prepared to spend a good deal of money on that?—Most certainly.

19878. And all that you are asking the Commission is that, by means of our experts, we should from time to time give you, after inspections, criticisms and suggestions?—That is what we come here for.

19879. You do not wish us to carry on the investigation?—No, certainly not.

19880. (*Mr. Power.*) Have you any reason to think that if very serious experiments are carried out, with the view to meeting this difficulty, time would not be given you by those who are opposing you at present to obtain these results from these experiments, and possibly the report of the Commissioners thereon?—I think it would be only reasonable that these gentlemen should do so, if the Royal Commission asked them, and they were satisfied that these experiments were being carried on seriously, and that you were prepared to report, say, next year.

19881. (*Sir William Ramsay.*) And you suggest that the riparian proprietors should be asked to confer with the Commission in regard to the whole matter?—Yes.

19882. (*Major-General Carey.*) Has the action of the riparian owners been directed against all distilleries whether they are doing anything, or whether they are doing nothing?—Oh, yes, against all distilleries.

19883. (*Chairman.*) There is just one point, Dr. Cowie; do you know anything about certain experiments, either suggested or actually now being carried out, by Dr. Russell Duncan, at one of the distilleries at Craigellachie?—I understand that he had a demonstration the other day on a small scale in Elgin, and I understand that at present there is some little hitch, that his machinery is not ready. We had hoped to have had Mr. Mackie, at whose distillery that experiment is being carried out, present here to-day, but he has not been able to come.

19884. Have you any knowledge yourself of the process, or are you at liberty to tell us?—I have no knowledge personally, but I hear he finishes up by electrolysis, and that he adds lime, and some other salt, and filters through some film that is produced.

19885. At present neither you nor any of the gentlemen are able to say anything about the experiment?—(*Mr. Robertson.*) I have seen the plans of his machinery, but I am not sufficiently expert—I might be able to answer some questions upon it, but I could not describe it.

19886. We will not endeavour to get any information upon it until the experimenting is in a more forward state?—I think, in Craigellachie, he has not begun to run yet, but they are taking it up very seriously. The directors are certainly going to give him every facility. They do not object to spend money in order to try and arrive at the practical outcome of this process, but I cannot explain the process, though I have seen it.

19887. (*Mr. Power.*) Is the experiment on something more than a laboratory scale; is it on a large scale?—I understand it is to cure the output of the distillery altogether. He has done it under certain guarantees, and the distillers have granted him several amounts, I understand.

19888. (*Sir Michael Foster.*) At the expense of that particular distillery?—They have granted him certain expenses, and they will pay him so much if he will cure; I do not know what the arrangement is, but I know it is a mutual arrangement between them.

19889. (*Chairman.*) Then, probably, much of the difficulty, Dr. Cowie, has arisen in consequence of the distillers having for a long time not recognised the necessity for dealing with their waste products?—Well, I think it was in 1896 that the question first came before distillers, and the history of the thing was this: Distillers were then asked by riparian proprietors to do something, or they were told that they must carry out the provisions of the Public Health Act or the Rivers Pollution Act, which stated distillers should dig pits on their own ground, or as near as possible, for the settlement of the stuff before running it into any ditch. That was done. That would be about 1898. Everybody had these sand-pits. The result was most disastrous. Whereas the burnt ale being put into the stream does not produce *leptometus lacteus* to any extent, this stuff, in percolating through the sand, although perfectly clear, had a most acid, acrid stench, and the streams were covered for miles down with this *leptometus lacteus*. Then it was obvious that would not do. The next thing was what was to be done with that; so we began experimenting on various lines. That experiment that Mr. Robertson has been talking of has been going on, I think, since 1899. (*Mr. Robertson.*) Yes, 1899. (*Dr. Cowie.*) Since that time I have been experimenting on the other line, and, of course, it all takes a little time, and you have to turn round so often; but I may say this to the Commission, that at every turn we have been driven further and further. The screw gets another turn, and we are now getting so tightened up, that we are at an *impasse*. You see from what you have heard to-day, that if you put the stuff into the stream without making it absolutely pure water, you are immediately attacked; if you put it into the air by destruction it creates a smell. Then the landowners immediately say, "You are polluting our grouse moors, and we cannot have that." It is also very difficult for a manufacturer situated as I am, or as Major Grant, of Glengrant, in Rothes, to put up a plant of that sort, because of the smell coming across the village you will have interdicts fired at your head from every quarter. It is not as if we were in a city where there is a number of chimneys and a number of smells, such as Manchester, but we are out in the country in pure air, and any little thing like that soon attracts the notice of anybody who happens to come along.

19890. (*Sir Michael Foster.*) I rather gather, Dr. Cowie, that no very distinct effort has been made to modify in any way by any contrivance the smell which comes from burning?—They have tried in every way possible by putting on subsidiary furnaces to modify this smell, but, so far, without any very satisfactory results. (*Mr. Robertson.*) We do not want to burn the stuff; we lose weight. We want to dry it. This is entirely new.

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19891. The smell is in the drying?—In the drying. If it is burned there is a smell, but there can be no objectionable smell if you can regulate the drying and heating process, and that is the experiment we are making.

19892. (*Chairman.*) No difficulty arises in the first evaporation process, reducing the waste products to the condition of syrup?—Yes, burnt-ale entirely; we are not treating of these.

19893. Up to that point no difficulty arises?—None whatever.

19894. The steam arising does not cause smells; it is the final burning up of the syrup?—Yes; we are drying in vacuum, reducing in vacuum to syrup.

19895. (*Sir Michael Foster.*) It is the drying process previous to incineration?—Well, we have to run the syrup out into a vat.

(*Dr. Cowie.*) To make it a manure.

(*Mr. Robertson.*) We run it on to pans, and then run it on into a flue and let the heat pass over it; the waste heat from the furnace for driving the evaporators, heating the evaporators.

19896. (*Chairman.*) No evil arises from the first evaporation?—None at all; none whatever.

19897. Have you tried experiments for the slower drying of the stuff into solid matter?—Yes. I think that means room, because the heat comes into the flue at a certain degree which would burn at once. We have to carry the flue a long way, and then put into the flues. To dry that means room—a shed—an expense.

19898. I admit these experiments at the expense of individual distillers are very serious things indeed?—They are indeed; I can speak for ourselves.

19899. The distillers of Scotland do not recognise the advisability of forming a fund to carry on on their general behalf serious experiments in this direction?—Yes, of course they are all doing something.

19900. (*Sir Michael Foster.*) That, I gather, has not been done?—One distiller says, "That is the way to do it"; another says, "Well, I know it can be done in this way, if I just get enough time to carry out my experiments." Therefore it would be a little difficult for them to combine under these circumstances. (*Mr. Grant.*) Every distiller is so differently situated; it is impossible for distillers to combine to do things like that, because every distiller, owing to the situation of his distillery and one thing or another, must carry out really his own arrangements. If the distillers were all together we could easily combine, but we are all differently situated on different points.

19901. (*Chairman.*) Well, we can only gather information on these points. We can only take for what it is worth your statement that such a combination is not possible?—I do not think so. (*Mr. Robertson.*) Take a distillery like Ben Rinnes, which is six miles from a station—I am not quite sure, but the mileage is very serious; if they were to undertake evaporation, say, on the process that we are doing, well, the coal costs £1 now in order to get to Aberlour, and it is up hill the whole way. I do not know what it would cost at the other end; anyhow they would hesitate to evaporate; they would have to use perhaps 10 tons a week, and they are only getting 3–5 tons of bye-product.

19902. I think, Dr. Cowie and gentlemen, it is not necessary to detain you further. The Commissioners have listened with much interest to the facts which you have put before them. It will probably be possible for the Commission to hear what the riparian owners may desire to put before them, and they will then have to consider the whole matter?—(*Dr. Cowie.*) I have to thank you, Colonel Harding, on behalf of the deputation. (*Mr. Mustard.*) Excuse me, Mr. Chairman; there is one thing, which is a very important thing—if we can get a standard of purity fixed for our effluent, suppose we get 90 per cent.; we could purify up to 90 per cent. if we could put into the stream at 90 per cent.

19903. Do I understand you to say that it would be a facility to you if some standard could be named?—Most certainly; and mind you, Mr. Chairman, we are probably the most important manufacturers in Scotland. We cannot put that to you sufficiently strongly. We pay £15,000,000 to the Revenue every year— to the Imperial Revenue; you cannot forget that.

19904. Yes; but what really interests us is your observation, Mr. Secretary, and that is this—that you think it possible to purify to the extent of 90 per cent.?—We can purify up to 90 per cent., but we cannot put it into the stream exactly as river water—it is impossible; and if we are not allowed to do it we have got to stop our business.

19905. The statement you make to us I take to be official, made in the presence of so many gentlemen?—That is so.

19906. That you can see your way to purify your effluents up to 90 per cent.?—That we can see our way to purify our effluents up to 90 per cent.; is not that so, Mr. Doig?

19907. I did not gather that from the answers.

19908. (*Sir Michael Foster.*) By which of the various processes—by all of them?—No, I told you one—lime, phosphate of lime, and boiling up to 212 degrees, the bacteria beds, putting it through beds; that is the best effluent ever I have seen.

19909. (*Chairman.*) A chemical settlement following upon boiling?—Boiling up to 212 degrees.

19910. And then passage through bacterial beds?—No, that after; through lime, superphosphate of lime, and bacterial beds, and you will have over 90 per cent. of purification.

19911. (*Sir Michael Foster.*) I think your point, Mr. Secretary, is this—that if by any of the processes it can be shown that you can achieve a purification of 90 per cent., the riparian owners ought to be content with that, and not insist on absolute purity?—That is so, and for goodness' sake let us have a friendly interview with them and keep us out of the Court of Session.

19912. (*Chairman.*) Are we really to take it from you that you can so deal with it as practically to reduce the impurities to 90 per cent.?—Yes, we can.

19913. And that the distilleries are prepared to undertake the expense that may be necessary to obtain that 90 per cent.?—I cannot guarantee anything. (*Mr. Robertson.*) In connection with burnt-ale, of course, I can safely guarantee this percentage.

19914. (*Sir Michael Foster.*) Is Dr. Cowie able to guarantee a purification up to 90 per cent.?—(*Dr. Cowie.*) I do not quite understand what 90 per cent. of purification means. I am not prepared to answer the question.

19915. (*Chairman.*) You are referring to burnt ale?—Burnt ale, certainly.

19916. I take it in regard to the other difficulties, the difficulties would not be greater, but less?—(*Mr. Robertson.*) Oh, certainly; that is, our own experiments have led us to come to that conclusion. (*Dr. Cowie.*) In this process that Mr. Mustard refers to, you add all your other effluents to cool the liquor—the supernatant liquor there, after precipitation.

19917. (*Sir Michael Foster.*) So that when you are dealing with burnt ale you are dealing with everything?—(*Mr. Mustard.*) Dealing with everything; you would require to use all your other liquors to cool your boiling liquor.

19918. (*Chairman.*) Where is your experiment being carried out?—You will see it at Aberlour, and you will see it at Mr. Thorne's place, but we have not got the heating into Dailuaine just yet, but it will be in a fortnight.

19919. Then you are not able as yet to give the Commission any definite data in regard to the result?—(*Mr. Mustard.*) We will give you the samples, and I will guarantee to give you them within a week. I think at Dailuaine we must be precipitating up to 90 per cent.; precipitating in the tanks; this boiling process is simply to ensure that precipitation.

19920. You are satisfied from your knowledge of these experiments that you can reach the 90 per cent. degree?—We believe our effluent is absolutely innocuous, but we do not know whether our opponents are satisfied or not; they will not express an opinion.

19921. But you have 90 per cent. of purification?—Yes.

19922. And you are prepared to spend money to get that 90 per cent.?—We are prepared to spend any money.

19923. (*Sir William Ramsay.*) Is there any market for your sludge?—We are not precipitating by that process at present. (*Dr. Cowie.*) Like the recovery process, it is very easily dried, this sludge, and should be worth something, but the thing is too new to speak much about it. The difficulty is that time is required. I have to thank the Commission for their courtesy in seeing us so early, and giving us such a patient hearing.

SIXTY-NINTH DAY.

Tuesday, 10*th May*, 1904.

PRESENT:

The Right Hon. the Earl of Iddesleigh (*Chairman*).

Sir William Ramsay, K.C.B., F.R.S.
Major-General Constantine Phipps Carey, C.B., R.E.
Colonel T. W. Harding, J.P.
Dr. James Burn Russell.
Mr. T. J. Stafford, F.R.C.S.I.

Mr. F. J. Willis (*Secretary.*)

ALSO PRESENT:

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

The Duke of Richmond and Gordon, Mr. John R. Findlay, Mr. W. S. Menzies, and Mr. J. H. W. Grant, called in; and Examined.

The Duke of Richmond and Gordon, Mr. John R. Findlay, Mr. W. S. Menzies, and Mr. J. H. W. Grant.

10 May, 1904.

19924. (*Chairman.*) My Lord Duke and gentlemen, In the first place, it is our duty to thank you very much for your kindness in accepting our invitation to come before the Commission to-day, and I should wish to explain that a part of our reference imposes upon us the duty of investigating the disposal of trade effluents, and that our attention having been called to the question of distillery refuse in Scotland last year, some of our members visited Scotland, and, as a result of the visit, we came to the conclusion that the question was one of magnitude and difficulty, and that a great deal of consideration on our part would be necessary before we could make any report on the subject. Well, this consideration we shall undertake as soon as we possibly can; that means, as soon as our officers are free from the occupations on which they are at the present moment engaged, and which we cannot very well interrupt. The next thing that happened was that early this year we received a request from the Scotch distillers that we would receive a deputation on their behalf, who would be able to lay their views before us, and to this we agreed, and I believe that the report of what passed at that deputation has been sent to you?—(*Duke of Richmond and Gordon.*) Yes, we have had a copy.

19925. We understand that the position that the distillers take up is that no one knows at this moment what the best practicable means of purification are, but it is hoped that our investigations may settle this question, and the distillers argue that they should not spend money now in large amounts, because that money may prove, in the light of possible further knowledge, to have been thrown away; in fact, to put it shortly, as far as I can make out, what they want is that the present state of things should be allowed to continue until our investigations have been completed, and we have reported what means are available and practicable for the purification of this refuse. In the meantime, they propose, at least I presume they do, that they should make such temporary arrangements as are necessary. Also, I understand that they are quite willing to carry out any experiments that we may suggest, and it is by their request that we have ventured to approach you. I can only again say that we are very much obliged to you for your kindness in coming here, and that we shall listen with the greatest possible interest to any views that you may place before us?—(*Duke of Richmond and Gordon.*) Perhaps I should say, first of all, that Sir Charles Logan (who represents the Countess Dowager of Seafield) and Sir George Macpherson Grant are unable to attend. They are neither of them very strong. I saw Sir George yesterday, and he said he would come if he could, but when I saw what the morning was, I felt convinced that he would not be able to come. Sir Charles Logan and I have been in correspondence, and I am justified in saying that although they are not here, they are cognisant of my views, and are entirely in accord with them; so I think you may take it that although there are only four out of the six who were originally invited, they will confirm and stand by any statements that we make to-day. Well, then, first of all, perhaps it would be as well if you told us to what extent you want evidence from us as to the spawning facilities that exist on the Spey; I mean, whether you wish us to go into a description of the river, or simply to deal with the matter, taking that for granted that there is fishing in the Spey, and that spawning beds are a necessity to continue the breed, whether you wish us to give you any account of the condition of the river, or whether you simply wish us to deal with the statement put forward by the distillers, of which we have all had a copy.

19926. I think we may take the state of the river for granted. Some of our Commission have visited it?—I believe some of the Commission have been north.

19927. Yes?—Then, of course, the condition of the river, the formation of it, the spawning beds, and so forth, that, as a matter of fact, nobody can gainsay. Then there are one or two points that Mr. Grant would perhaps like to deal with himself, as they have occurred on his water; Mr. Findlay, too, has one or two spawning beds, which he would like to mention, which he has been more immediately concerned in than I have; but I may say generally that the negotiations with the distillers first commenced some years ago. I forget the actual date of the first communication that passed between the proprietors and the distillers, but it was some ten or twelve years ago—something of that sort; I would not be sure of the year, but if you wish for that I can get all that for you.

19928. Oh, no?—Then I need not go into detail, I daresay, of the number of distilleries which are on the river now, or the bushels of malt that they deal with every week.

19929. No?—But I may make a general statement, that within the last ten or twelve years the number has enormously increased. Possibly some of the Commissioners who have been up there have got all those facts, but I think I cannot be too strong in pressing the fact that the increase has been beyond anything that was dreamt of. Well, there is a tributary of the Spey, the Fiddich, which runs to a great extent through my property, and some years ago that was one of the best spawning beds in the district; the fish went far up—I have got a shooting lodge there—900ft. above the sea, and the fish used to go and spawn there and beyond, winter after winter; they used to get as far up into the little river not much broader than this table; some of you may have seen. Well, now there is not a fish, there is not a fish of any sort or kind comes up there. When they leave the Spey, about the point of leaving the Spey, they are met face to face with this enormous mass of pollution, which comes out of the Fiddich itself, and the condition of the Fiddich itself—I should have liked some of the Commissioners to have seen it in the summer time, in the spring time at any rate, when the water is low, the condition of absolute filth to which the distillers reduce it—slime and fungus through it from side to side. I am surprised that any fish get through it at all. Of course, when you get a heavy water or a big spate, or anything of that sort, this pol-

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lution gets to a certain extent diluted. There is a certain number of fish who will force their way through, but I do not think I am over-stating the case in saying that there is not one fish in the Fiddich now to fifty that there were ten years ago.

19930. And the refuse discharged into your river has increased beyond all expectation?—Oh, yes, distillery after distillery went up. I suppose there is some special quality about the water there, which enhances the quality of the whiskey, and they came dropping down there one after another. Mr. Grant reminds me that not only the new ones arrived there but the enormous additions that were made to the buildings and the producing power of the old ones. Well, I mentioned the Fiddich first, because I am more directly concerned in that as a spawning bed, but you may take it the same condition prevails on the Spey beds, especially on Sir George Macpherson Grant's property and on Mr. Findlay's, and on Mr. Grant's and on Lady Seafield's waters. Those are all above the Fiddich, and Sir Charles Logan would have told you, but Mr. Grant will tell you, that the spawning beds on his property used to be notorious for holding spawning fish in the breeding season, and now the difficulty is to find a pair there at all. Well, I should like to mention a point—certainly it is only inferential you may say, but I think it is not an unfair inference to draw—that fish will not face this enormous mass of pollution which comes down the river. In the last few years the number of fish that spawned in my water—that is to say, the last seven or eight miles of the river down to the sea—has enormously increased. I could not tell you the actual increase, but you will see the spawning beds. There are fish now which spawn down to within a quarter of a mile of the tide, which comes a little way into the river. It does not really come into the river, but it rather backs the river up. Well, the number of fish which spawn down in the lower reaches now is far in excess of anything that was there before the pollution, and this increase has been contemporaneous with the increase of the distilleries and the consequent pollution which they put into the river; and I do not think it is an unreasonable inference to draw that the fish find the river in such a state that their nature rebels against trying to force their way through all this pollution, and they have stopped and spawned in the first place that they can. There is an idea that you cannot make good whiskey in hot weather, but, at any rate, distilleries must shut down for a certain time in the summer for cleaning out purposes, and then they start full blast immediately after the harvest, when the first of the barley crop becomes available, and I suppose the distilleries are worked at their heaviest about the month of November, and that is the time in ordinary years there is a very large number of fish which would be trying to force their way on up to the spawning grounds. Consequently, those fish which now spawn down below are the fish which, I think, if the river was in the proper condition, would have gone further on. And I may mention, too, that with regard to that—of course, I know it is not a very strong argument, this one that I am putting forward, but I think it is a fair inference to draw as suggesting the amount of damage that pollution does—I should say that the spawning beds on the lower reaches of the river are far less productive for the number of eggs deposited than those higher up. And for this reason: that the lower pools of the last three or four miles of the river are much shallower, the whole bed of the river down there is very much higher up than it is further up the river, and there are no retaining banks—the river may be here to-day and 150 yards further east or west in a couple of months' time, and those lower spawning beds are very much more liable to damage for that reason from spates than those further up the river. I should like the Commission just to take a note of it, although I admit the argument is not a very strong one, perhaps, but I think it is a fair inference to be drawn. Then there is no question but the pollution of the river affects the rod fishing. I do not go so far as to say that it will kill mature fish, but from the experiments that we have tried it will kill the young fish, the fish shortly after they are hatched. It kills them. I think you have a case quoted here? (*Mr. Grant.*) Yes. (*Duke of Richmond and Gordon.*) We have carried out experiments taking specimens of the water from below the distilleries, from below where the distilleries put them in; we have taken that down to our hatchery, where we hatch out about 800,000 or 900,000 eggs every year, and putting the young fish in, in some cases they died after two or three minutes. It is not a question of the water which we took having been kept and have staled in any way, but it has been taken at once from the river to the hatchery, the young fish have been taken out, and there they have died right away; they made no effort, and if that happens in such a case as that, I think it stands to reason that the same process must be going on wherever there is a spawning bed in the vicinity of an output from a distillery. Well, if any of the Commissioners were fortunate enough to see the deposit that is left from the pollution which is put in by the distilleries I think that they would be very much astonished; I am not aware that any of them have, but down below me—and I am seven miles, I suppose—the point I am speaking of is some six miles, at any rate, from the nearest distillery—you see the stuff coming down the river, and it will settle in eddies, and wherever there is a slack corner, and wherever the river goes back, it leaves a foul black slime. Now that happens miles and miles, mind you, six miles away from the nearest point where it is put into the river, and that must be surely far more deleterious in the neighbourhood of the distilleries than it is at the point I am speaking of. It comes down in various shapes, in various forms; I have no knowledge of chemistry, so I cannot explain the component parts of it, but it comes down in various shapes and forms; it comes down sometimes in the shape of a white froth, and many, many times when I have started out on the river fishing I have arrived there, and I have said, "Well, it is no use fishing to-day; the river is white from side to side;" you see the river covered from side to side with patches of froth, and in some cases froth coming down in pieces as large as a hat-box, for instance.

19931. (*Sir William Ramsay.*) Are you speaking of the Spey or the Fiddich?—The Spey, oh, yes; and was just going to say——

19932. (*Colonel Harding.*) Is the observation of the Duke referring to the present time or some distant time?—Oh, last autumn and this spring. (*Mr. Menzies.*) This spring too.

19933. This is a recent observation?—Yes, this spring. (*Duke of Richmond and Gordon.*) I can guarantee you can see it there to-day. (*Mr. Menzies.*) I am sure you could. (*Duke of Richmond and Gordon.*) But I am not putting this forward merely on the sporting ground; it is a far more serious matter to us than the fact that I or my three friends here are not able to enjoy a day's fishing ourselves. A continuation of this is bound to have a very serious effect upon the value of our property. There are many people who are fond of salmon fishing, and who will give a good deal of money for it, but if this condition of things on the Spey is to continue, unless something is done it must get worse, and the value of our fishing properties will be very prejudicially affected. And on that point I may say that we feel rather sore about this, because we have had to spend for some years past, year after year, very considerable sums of money—for what? Simply to preserve our property to ourselves, the injury to which is being caused by the distillers who have started all these enormous works, and we were there before they were, and our contention is that they have no right to come down and not only injure our property for the moment, but it is a thing of this sort, if some check is not put upon a thing of this sort, the permanent value of the place will be more prejudicially affected than it is for the moment, because as the pollution goes on the river gets worse and worse, and worse and worse, and the prospects of any value attaching to it become more remote. It is mainly on those grounds that we complain of the pollution being put into the river. I think your Lordship said—I understood you to say—that later on your experts were going to take up the actual question of the component parts of the pollution.

19934. (*Chairman.*) Quite so.—So I need not bother you with that. Well, then, the point that we feel strongly upon is this, that we have been, we consider, patient beyond words in the action that we have taken against the distillers. I told you when I began my remarks that it was some years ago that we first took any steps, and we have been met by various pleas put forward by the distillers. Some of them have said, "Oh, we are very sorry that we are polluting your river; we do not want to do you any harm; nothing is further from our wish than that." Well, that is very well as

far as it goes, but that is where they stopped. Well, then, again there are some who admitted they were polluting the river, and maintained they had a right to do it. Others, again, said, "Well, we will see what we can do; perhaps we can do something;" but nothing in the way of asperity on our side has ever entered into any of our communications with the distillers. Perhaps you would like me to tell you the process we have adopted in our dealings with them, how we have set to work?

19935. Yes, we should.—Well, we saw in the early days that this was going to be a very serious question, and we put the matter into the hands of our Edinburgh lawyer, and all these distillers have from time to time been written to. We have taken samples of the effluent coming from their distilleries; they have been written to; their attention has been drawn to the fact that they were putting pollution into the river, and various replies and correspondence have passed between us and them. They have asked—those who really wanted to do something have asked for time, and said they would try and see what they could do, and time has always been given to them. It is only in two cases, where we saw that that could not go on any longer, that we took them into the Court that we have done so. There is one case, the first case, which was against a man named Kemp, in the Maccallan Distillery. There we succeeded, and he now has put in certain remedial works. Well, it is close to you, Mr. Grant; you know better than I do what the condition of the burn is. (*Mr. Grant.*) It is much improved.

19936. It has been much improved?—It is not on my property. (*Duke of Richmond and Gordon.*) The Maccallan. (*Mr. Menzies.*) It is very small; they put it all on land; it is a very small distillery. (*Duke of Richmond and Gordon.*) We have never threatened them needlessly; it is only when matters have become so serious that we saw the only course we could adopt to preserve our property was to take them into the courts, and we had an action against Kemp, of the Maccallan Distillery, and we were successful; and we have had another action, in which we got an interdict against the Daluaine Distillery. That is on Mr. Grant's property, and another one further up the Spey, on Sir George Macpherson Grant's property. As a matter of fact, I should say that the Daluaine people are not satisfied with the decision of the Court of Session in Edinburgh, and they now propose taking it on to the House of Lords.

19937. You say that possibly one of these cases is going to the House of Lords?—Yes.

19938. And that will be the first time the House of Lords has had a case before them?—Yes; the decisions of the two Courts in Edinburgh have been in our favour, and the distillers are not satisfied with them, and they propose to take it on to the House of Lords. I think those are generally the principal points which you would wish to be informed upon, and, if you like, I might make one or two remarks on some of the suggestions put forward by the distillers.

19939. Might I just ask you two more questions?—Certainly.

19940. In the first case you mentioned, in which proceedings had been taken, the distiller, I understand, took steps to remedy the mischief?—After we got an interdict against him.

19941. Yes; but are those steps satisfactory; that is to say, if such steps as these had been taken generally, would that probably have solved the difficulty?—Well, I would not like to go so far as that. You see, it is not a very large distillery, and he has facilities for disposing of his stuff, which come easier to hand than in the case of the distilleries which are malting a very much larger quantity. It is partially successful. I think it is simply a question of time really how long his will last. (*Mr. Findlay.*) At present the burnt ale is all carted away; it is pumped up into a big tank at the top of the hill, and there are several farmers round about to cart it away. As far as the burnt ale is concerned, I understand there is no process of purification adopted. (*Duke of Richmond and Gordon.*) It is simply removal, complete removal.

19942. In the case to which your Grace referred, where you noticed the stuff coming down to a distance of six miles, I suppose the refuse would be turned straight into the stream without any treatment at all?—Except in one or two cases, it has had no treatment at all anywhere yet.

19943. The treatment is rather the subject?—There are three or four distilleries at Rothes; there is one very large one belonging to Mr. Grant, not this Mr. Grant, but Mr. Grant who was before you the other day, and there the whole of the effluent from their distilleries comes straight into the Spey through the medium of the drains of the Burgh of Rothes.

19944. Without any treatment at all?—Yes, they have rather got—the distilleries there have rather got the best of the Burgh of Rothes. When the Burgh of Rothes put up a drainage system of their own, they originally did not contemplate—I think it is the bacterial system there—having to take all the refuse from the distilleries. The distilleries were a valuable asset to the town of Rothes, because they were very highly rated, and they found that they could get the use of the Rothes drains; consequently—well, I presume this is the fact—they said to themselves, "What is the use of our putting up remedial measures at our distilleries? Rothes drains take what we put away; Rothes are the people to purify." The consequence is, the whole of the pollution from these distilleries goes straight to the Spey. Whatever purification they have got at Rothes is no use at all; it is a farce.

19945. Any purification is rather the exception than the rule?—(*Mr. Menzies.*) Entirely the exception.

19946. In the present state of things, purification is rather the exception than the rule?—(*Duke of Richmond and Gordon.*) Oh, yes; and where it has been tried I quite admit that the distillers have had some difficulties to face, because absolute purification is very difficult to achieve; there is no doubt about it; but where we feel so strongly, is that they have taken so little heed of all our early representations. In some cases they have put up settling tanks; they might just as well have put basins for all the practical use they are, in taking away anything but an infinitesimal portion of what was coming from the distilleries, and it was not until they saw that the law was on our side that any of them really took up the question earnestly, I believe, then, with the desire to see what they could do. It may be an expense to them, but, as I said a little while ago, it has been a great expense to us to preserve—endeavouring to preserve, for we have not succeeded in doing it yet—in endeavouring to preserve our property, and if we have had to spend money doing that, they ought to spend money to do it on their side.

19947. Then, may I ask whether the number of fish have diminished within the last ten years?—Oh, on the upper waters, yes, but in the lower waters, where the pollution becomes more diluted, the falling off has not been so marked, but that tallied with what I told you just now about the inference I drew from the number of fish spawning lower down.

19948. Would the number in the lower waters be actually increased, do you consider?—No; I beg your pardon, I do not quite understand.

19949. Well, as far as I understood, there are more fish spawning in the lower waters now than formerly?—Yes.

19950. And would that actually increase the number of fish caught in the lower waters?—No; the number actually caught with the nets in the lower waters remains about the same; it has averaged the same for a good number of years.

19951. And the number in the upper waters has decreased?—Has decreased; oh, yes, that I admit.

19952. (*Major-General Carey.*) Is there any record of the number of fish taken annually on the Spey?—Yes; my net fishing is recorded.

19953. I mean the upper reaches?—I should think everybody——(*Mr. Menzies.*) I should think everybody has books; all your country and mine any way; it has gone down to nothing virtually.

19954. (*Chairman.*) Does the state of the river vary much; does the fact of the shutting of the distilleries in the summer produce any appreciable result on the state of the river?—(*Duke of Richmond and Gordon.*) Does what?

19955. Does the river appear to be less polluted when the distilleries are shut?—Oh, yes.

19955*. Very much less?—If you were there in the month of August, a good many of them are beginning to shut down now or about the 1st of June, but June, July, and August, then there are a few of them, working there may be some who have got a

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large amount of orders, begin making early in July, but, as a rule, it is the end of August or the beginning of September or even later before much work goes on, and if you are on the river in that time of year, you will see she goes down perfectly clear, no froth ; until the distilleries begin again you will see no froth on her at all, and you will see also none of that slime and fungus. If you get a small water about the spring time when the pollution is coming in in considerable volume, there is a large amount of fungus forms at the bottom of the river, and then, if you get a spate, I have seen it down below Fochabers Bridge coming down in lumps like sponge as big as my fist ; you have seen it as well. (*Mr. Findlay.*) Well, I am not there at that time of the year. (*Duke of Richmond and Gordon.*) Well, you have. (*Mr. Grant.*) I have. (*Mr. Menzies.*) It is worse in my country than anywhere.

19956. (*Sir William Ramsay.*) Can you get information as to how many distillers in the Spey district treat their refuse?—The total number ; if I remember rightly, there are something like 150 to 180 distilleries scattered through the district. (*Mr. Grant.*) Not on the Spey—about 20. (*Mr. Menzies.*) About 30 or 32. (*Duke of Richmond and Gordon.*) I have got it here. (*Mr. Menzies.*) I forget what there are over Scotland. (*Duke of Richmond and Gordon.*) You see, the Spey district covers a considerable area of country.

19957. Yes, I know?—In the year 1850 there were seven Spey distilleries, only eleven, and they only malted about 2,270 bushels a week. I have not got the particulars beyond 1900, but I do not think there is more ; likely there might be one less probably since 1900, because the distillery trade has had a severe blow.

19958. My impression was that they were numerous?—(*Mr. Findlay.*) I think the map is behind you. (*Duke of Richmond and Gordon.*) In the year 1900 there were 27 distilleries malting 50,850 bushels of malt, as against 2,800 in the year 1860.

19959. They look to be about 25 or 26—something like that. My point was this, how many of these are taking any steps to purify their effluent?—I can get that for you ; I would not like to pledge my word.

19960. We were told how many?—(*Dr. McGowan.*) Seven or eight, I think.

19961. (*Sir William Ramsay.*) Seven or eight? (*Duke of Richmond and Gordon.*) The majority of them are doing something, but the majority of them are doing so little that it is no good ; a good many of them have not faced the seriousness of the position yet.

19962. We have been shown various methods, some of which appear to be more successful than others. But my point was this : Have we only been shown those that were attempting to purify their pot-ale, and are there are a great many there which have not been doing so?—(*Mr. Grant.*) At Rothes they have not done anything ; they have done nothing at all. (*Mr. Menzies.*) No ; but they are going to do the best of all ; they are going to put up the best. (*Duke of Richmond and Gordon.*) It is not for us to say. (*Mr. Menzies.*) No, it has nothing to do with us. (*Mr. Findlay.*) The chief thing they do with the pot-ale is to spread it out over fields, and as long as farmers are willing to take it, and a small distillery has a considerable extent of arable land round about, there is no difficulty.

19963. Quite so ; but is there any difficulty in distillers getting land near their distilleries to put up plant for artificial filtration?—(*Duke of Richmond and Gordon.*) Oh, not if they pay for it.

19964. It is quite possible?—The land could be got. I do not think they could get it at purely agricultural value ; I do not think they would expect that.

19965. Because it is not agricultural land, but is valuable as building property?—Because it is for use for a purpose which will not really benefit the property ; it is not like feuing plots to improve a district. (*Mr. Findlay.*) If it reverts to the landlords, it is no use, as it is covered with concrete tanks or beds with sludge in them, therefore you cannot expect them to part with it at agricultural value.

19966. Quite so?—It would be useless for agricultural purposes for all time to come.

19967. But if the process of sprinkling it over the land were adopted?—(*Mr. Grant.*) I can speak with a certain amount of knowledge on that point, because in this case against the Daluaine Company, the Daluaine Company I understand have a private arrangement with my tenant, who is also one of the managing directors of the Daluaine Company, and they are the joint tenants of the farm, and they applied for help to me to put the burnt ale on to the farm of Daluaine. Well, if you put burnt ale on to land, if any of you gentlemen have seen the result, you will find that it creates such tremendous crops that they threaten to be too luxuriant and rot in wet weather Also if you put on too much you can actually burn up the pasture. Now, it was a difficult point really, but in order to keep myself perfectly justified in continuing this action against the Daluaine Company, though it was very much against my wish, my private inclination, to give land as it creates an offensive smell near my own residence, being an enormous quantity I said I would agree on certain conditions, provided that this was not taken into court, and so I asked them if they would agree to any man of skill I put on. As far as I understand, I really did not go into the actual details very much myself. My agents proposed a certain gentleman, and the Daluaine Company would not have him. They then proposed Mr. Walker ; Port Lethen I think he comes from ; I know him very well ; one of the best known agriculturists in Scotland. I said I would expect him, and he should regulate the quantity, visit the farm, and find out how much of this burnt ale could be put on the land. When he came he said it was all in the nature of an experiment ; it had never been done ; he was not sure how it would affect the rotation of crops. This farm had been laid out by them chiefly for grass, and they have sprinkled on as much of this burnt ale in such a manner as Mr. Walker directs and they have put an extra stock of sheep to feed it off. Mr Walker informed me it is only a temporary measure. It is not right for me, with the case before the House of Lords, to go into any further points about this action, but I think at the same time I would point out that an expert, an independent arbiter, meeting me going over the land with one of the company directors, and the solicitor assured me that the continuation of burnt ale on land could not go on for ever, and also that even if it was put on if it was not to do damage to land it would have to be very carefully watched and very carefully regulated.

19968. I suppose most of the distillers hold from you, do they not? I mean they lease your property, is not that so ; or do they own it themselves?—(*Mr. Findlay.*) The majority of them are feus, the Scottish system of tenure.

19969. Of course ; I know, but it is from you?—Well, there are various proprietors. (*Mr. Grant*) There are various proprietors. (*Mr. Menzies.*) None from me. I was the only one that would not have one, except his Grace.

19970. It is a lease for a number of years?—(*Mr. Findlay.*) A perpetual lease. (*Mr. Menzies.*) They offered me any price I liked to ask ; I would not have them. (*Duke of Richmond and Gordon.*) Upon that point, certainly one of the largest distilleries in Scotland, one of them which gives the name of Glenlivet whiskey, is on my property ; it is far away up, and there is a large amount of land at the disposal of this distillery, and a certain amount of pollution would get through to the river, but not much. And then there is another distillery on my property at Dufftown, that of Dr. Cowie, the gentleman you saw here at the last meeting. But those are feus which my father before me, and I in succession to him, have succeeded to, but nothing would have induced my father to have given off land for a distillery—not from any temperance sentiments, but for the protection of his property.

19971. (*Chairman.*) I think you said, did you not, that the number of distilleries has increased considerably in the last ten years?—Yes.

19972. So that they, at any rate—those new distilleries—have been allowed by somebody to come and settle there?—Those at Dufftown are on the Duke of Fife's ground. I think I can explain that to some extent : the Duke of Fife owned a considerable amount of property in Dufftown and neighbourhood and some of the distilleries at Dufftown ; he sold the greater part of his property, and some of the land which he sold bordering on the Fiddoch was bought for distillery purposes ; whether he was aware of it at the time or not I do not know. He is a non-resident, so it would not concern him, perhaps. (*Mr. Grant.*) I have new distilleries on my property, and I put in these feu charters extremely stringent conditions where I could. The

question actually came to me to be whether I should accept these feus or not, and I, naturally thinking the law of the land decidedly meant and means that a man cannot deliberately set up an industry to destroy and spoil his neighbour, thought perhaps the common law as it now stands would be good enough, that is to say, water must pass in its original state and quantity from one proprietor to another. However, in order to strengthen my position, I have got new charters for the new distilleries on my estate; others I succeeded to, with very stringent clauses indeed. One condition is that they are bound to effectively purify pot-ale, and if they do not, I may in some cases forfeit their feus. I am speaking generally. Another condition in the charter is that if any measures provided by the distillers for the prevention of pollution are not effective I am entitled to have these pulled down and others adopted, the object being that six or seven years ago, when these charters were taken out, I was not going to commit myself as to the proper measures to adopt to prevent pollution, and I do not intend to commit myself now. I tell the distillers either that they are polluting the Spey or the air or that they are not, and if they are, to rectify it; and that is how the matter stands. One distillery I have got now—I am only speaking offhand; I have not got the copies of the feu charters with me, but I will give you the general terms of them—in this particular feu charter about a distillery on the Spey, and I made sure before I came here. I feued it to a man called Thompson; I put a tremendously stringent clause in, but he evidently did not like it, for he never worked for more than a few weeks; he never worked his six years. These conditions are considered somewhat hard, but I may say, without prejudice, that I certainly will not alter them, because if I do I should do not only myself an injury, but my neighbouring proprietors. Those conditions were put in not only to safeguard myself, but my neighbouring co-proprietors, and if the distillers choose to accept a charter with conditions in it they must stand by the consequences.

19973. But do you say that if they pollute at all they must give up distilling?—Pollution according to the common law—that is a thing I speak very strongly on, because I consider it would be a very great hardship, if not an injustice, that the law of Scotland should be altered to suit the convenience of distillers.

19974. I was only wanting to know what you would call a pollution? A thing that has been water and has been used for something else cannot actually become water again; it may become innocuous, but it cannot become water?—A large amount of this water which is used in distilleries is used for driving power; I mean, for instance, they would have a wheel probably worked by a burn to work the electric light of the place; well, the sort of stuff I mean is the burnt ale, and that, I understand, is possible to be treated. I am not here to commit myself as to whether it can be or not. I really do not know; I can tell you if I am satisfied with it, and I think that is as much as is to be expected.

19975. (*Sir William Ramsay.*) Is there any difficulty about the pollution of the air? Do the processes that some of the distillers resort to to get rid of their pot ale by burning or distilling it make a smell in the neighbourhood?—The Tamdhu Distillery Company erected on my estate a plant—I am speaking entirely without prejudice—a plant to deal with burnt ale. I understand it is consolidated by evaporation. It is a very large plant, and I believe it is very expensive to work, and from the deposit that is left they get the deposit and put it on a sort of tray, and then the residue is mixed with the tail race water. They then reduce the stuff that is left into a cake or powder, which they intend to use as a manure. In this process there was, and there is, a very strong smell of burning, which I myself have felt a good many miles from the place, and I wrote to the company some time ago, and said it simply could not go on, and I pointed out to Mr. Willis, who was up visiting the Tamdhu Distillery a short time ago, the farm where the farmer frequently complained to me of the smell, especially in hot weather, and the company admit practically there is a smell, because they are going to endeavour to remedy it this year.

19976. And if there were some process discovered, or if one of the processes which is at present used, were pronounced by competent authorities chemically and bacteriologically to purify the pot ale to such an extent that it practically is water, would you, as proprietors, be willing to give the distillers in the neighbourhood facilities to acquire land for putting up such a building to make it possible for them to do their best to remedy the evil; supposing it was decided, would it be possible to meet them? They complain, I understand, that they have not sufficient land; that difficulties are thrown in their way; if you recognised that they were doing their very best, and succeeded, I presume you would be willing to meet them on the ground that there would be a considerable advantage to you in their holding property of yours and paying a rent?—(*Mr. Findlay.*) I am not aware that any land has ever been refused to distilleries for such purpose, except under circumstances where it has been asked with the view of staying proceedings. For example, if a distiller is polluting, and you want to get a decree declarator that such a state of affairs is existing, they forthwith apply for land, and they want to take time by erecting remedial works, and to get the thing hung up in that way.

19977. I see?—I think any case of land being refused has been simply because it has been a step in the process of negotiation. (*Duke of Richmond and Gordon.*) Procrastination. (*Mr. Findlay.*) Procrastination. I do do not think there is any case of land ever refused where there was evidence that it was wanted for *bonâ-fide* purifying purposes. (*Mr. Menzies.*) No, I am sure there never has been.

19978. But has it been offered at such a high price that it was tantamount to a refusal?—(*Mr. Findlay.*) Not that I am aware of. (*Duke of Richmond and Gordon.*) Well, of course, I cannot speak to a certainty upon this matter for all the other proprietors, but in no case, as far as I am aware, has the price been prohibitive; it may have been large, but I draw a very broad distinction between a large price and a prohibitive one. (*Mr. Grant.*) I have never heard of a distiller commenting on the price of land with me as regards works; they have never come to me and said the rent is prohibitive. I have had a case where the man said the conditions of my feu for the proposed remedial works were prohibitive, but not the price, and I think that was significant.

19979. (*Chairman.*) Have you ever been asked for land for purification purposes?—Yes.

19980. And you have granted it?—No. I have never been asked for land to erect buildings on outside his distillery works, but I have certainly given facilities, as far as are in my power, for the burnt ale to be dealt with—tanks to be put up, so that the farmers might cart it away.

19981. (*Mr. Stafford.*) Do the riparian owners wish to encourage or discourage the industry?—(*Mr. Menzies.*) We wish it was in any other valley except the Spey. (*Duke of Richmond and Gordon.*) I have no personal feeling about it at all.

19982. But do they as a rule wish to grant land or not—the proprietors?—(*Mr. Menzies.*) I will not give any land.

19983. For the purposes of the distilleries?—For new distilleries. (*Duke of Richmond and Gordon.*) As I said just now, nothing would induce my father to do it. (*Mr. Menzies.*) They have asked many times, and have always been refused; I will not have a distillery on my property; that is a different thing. (*Mr. Grant.*) Personally, as long as they do not pollute my property at all, I have not got any personal feeling against them at all. (*Mr. Menzies.*) It is several years now since there was any idea of putting up a new distillery, because the crisis in the trade has been so bad we have had no applications for years.

19984. (*Major-General Carey.*) What proportion of the distilleries are doing nothing at all in the way of remedial work?—(*Duke of Richmond and Gordon.*) Well, I could not tell you off-hand, but I could get you the last report from Messrs. Brodie, our lawyers, if you wish to have it.

19985. The Commission, when visiting the Spey Valley, examined a number of works in which, at all events, attempts were made to produce a satisfactory effluent, some of them varying in success, but there were *bonâ fide* attempts made by tanks and filters?—Quite so.

19986. They were apparently doing their very best then, and they are anxious to get further advice if they can from the Commission?—And possibly you saw a comparatively innocuous effluent.

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19987. Well, we saw a distinct difference between the treated effluent, and when it was turned into the river without being treated—they turned it in to show the difference—the river was suddenly covered with the frothy matter?—Excuse my saying so; you do not know whether that distillery was malting to the full extent of its capability; you do not know how much of the effluent you saw was a fair sample of the amount that they would be putting in if you were not there?

19988. We took it simply that they were treating all the refuse?—On that I should like to make this remark: the distillers in some cases have tried to hoodwink us by putting the refuse in at night; they run off their tanks; we have found them doing that, and if they will do that to hoodwink us I should not be surprised that they might have had a try at you too. I do not say they have been successful, but I think they might have made the experiment.

19989. (*Chairman.*) I think your Grace said, in case you have not any more remarks to make, that one or two of the other gentlemen had something to say?—I have several more points I should like to put before you before I have done, and then the other gentlemen will have something to say. If you do not want to ask me any more questions on the general point I should like to make some remarks on the statement Dr. Cowie put before you when he was last here.

19990. Certainly?—He deals with the number of distilleries and so forth. The first remark of his which I take exception to—I will not say take exception to—to which I wish to draw your attention is this. He says:—"I must say that perhaps at one time the distillers, like other manufacturers, when this problem confronted them were a little slow to move till they saw how things would go, but I have to impress upon the Commission that I am certain every distiller is now anxious to find some way out of this trouble and to meet the complaints that have been made against them by the proprietors." There I have from Dr. Cowie's own lips the complaint which I mentioned some little while back that our appeals have had so little effect upon them that it is not until they find the law is against them that they really face the difficulty. We have been going on for some years spending money which, if they had taken the question up with vigour in the first instance we should have been saved, or, at any rate, a considerable portion of what we have spent we should have been saved. And then he makes one suggestion which I may say we are all dead opposed to, and that is, any idea of partial purification or the establishment of a central authority. In the case of partial purification, what guarantee have we that partial purification will continue? From our experience of the distillers up till now what guarantee shall be get that the partial purification which they suggest will be continued? I see in one place they talk about purifying up to 90 per cent. Well, I should have thought—I am not an expert in those matters—if you could purify up to 90 per cent. you could purify up to 100. The difference does not appear to me to be a very great one. But supposing you purify up to 90 per cent., what is the ultimate result? The result is the same, to use a homely simile, as filling a bath from a tap or a teacup; it is only longer, the time is only more extended during which the river will become in the same foul condition that it is now; if you have only partial purification it means that a certain amount of pollution is going in; it depends entirely upon the amount of pollution going into the river, how long or how short the time it takes the river to get into the condition which we are now complaining of. Do you see my point?

19991. I do not know that we should quite agree.—That I cannot help.

19992. (*Colonel Harding.*) I suppose the Duke's point is this: that if an effluent is purified to 90 per cent., and if in the course of time, owing to the expansion of distilleries, the volume of effluent is increased ten times, that the sum of impurities would be as great?—Well, to my mind it is only a question of time when you arrive at the same result as you have now. Given a certain quantity of stuff to go into a certain receptacle, whether it goes in in a large quantity or in a small one, it goes in in a certain condition, and it is a question of time how long it takes for that amount to fill a certain receptacle. Do I make myself clear?

19993. (*Chairman.*) Oh, quite so; but I think it possible that we may think the river would do a certain amount of purification itself, and it might be able to purify 10 per cent. quite easily without any damage to the river; but those are matters for the Commission?—Those are matters for the Commission to settle, but I just put them forward for the proprietors.

19994. Might I just ask you this: supposing purification was sufficient to make the water quite uninjurious to fish, is that all you want; I mean, it is not a question of health to human beings; it is a pure question of the fish that you are interested in?—Well, no; it goes further than that. Mind you, a large number of the proprietors who have land on the borders of the Fiddich—for instance, there are some cases in the Fiddich now in which it would mean injury to put your cattle on to drink it.

19995. The cattle drinking it, you mean?—Yes.

19996. Are there cases of cattle suffering from the polluted water?—I will not say. (*Mr. Grant.*) I think, speaking only from memory, that when the Glenfarclas Distillery was working at full power and putting the burnt ale straight down the Daluaine Burn, the farmers did not like to put their cattle to drink there. (*Duke of Richmond and Gordon.*) The point we want very strongly to put before the Commission is this, that our right is to have full pure water. We have been spending a considerable sum of money trying to get it, or rather, to preserve it, and our patience has been strained almost to breaking point now by the distillers. They appear to be, from Dr. Cowie's statement, very frightened of the Court of Session, and they suggest the establishment of some central authority to decide on pollution. Well, that is a point on which we are very strong. The Court of Session is the law court in Edinburgh, which is there for preserving our rights; we do not want any other body, any new body, or any other body set up and established for the purpose of dealing with this; the Court of Session is good enough for us, and probably the distillers are aware now that the Court of Session has decided against them, that the law of the land is in our favour, and I can quite understand that for that reason they might suggest setting up some other authority which they think might possibly take a different view. From what Dr. Cowie says, more than once, his dislike to the Court of Session is very evident. "Do keep us out of the Court of Session." "Can you not get the proprietors to arrive at some arrangement with us, and avoid the Court of Session?" They all appear to be frightened of the Court of Session, which I consider a very healthy sign. And I do not think, with regard to the question of a central authority, that they need have this fear of the Court of Session which appears to be coming before them, because they have been very fairly treated in the Macallan case. Lord Kyllachy was the judge, and in that and every other case that we had had up no onerous conditions had been imposed upon the distillers, but rather they had been granted time. In the case of the interdict that we got in this particular case, which was decided by Lord Kyllachy, they got a year. (*Mr. Findlay.*) It was suspended during the pleasure of the Court. (*Duke of Richmond and Gordon.*) All those interdicts have been suspended until the distillers have had a considerable amount of time to endeavour to make some arrangements. Well, then, I see Dr. Cowie in one place says—I think it is Mr. Grant, it was not Dr. Cowie, there. He says Dr. Cowie has said they have no wish to adulterate the rivers. I daresay they have not, but our complaint is that they do.

19997. May I ask you when the first case that you took action against them was?—(*Mr. Findlay.*) The Kemp case began in 1895—at least, the correspondence. (*Duke of Richmond and Gordon.*) It was concluded in 1898. The date of the reclaiming note was October, 1898.

19998. Then the decision had been given in your favour in October, 1898?—It went on for two years, but that was the date of it.

19999. That was the first case?—That was the first case.

20000. But you still find it the exception rather than the rule that any steps are taken to purify?—I wish you could see it any Friday or Saturday afternoon. With regard to that, you say it is the exception to have taken any steps.

20001. Yes?—I wish to be perfectly fair about it; I will not quite go the length of saying it is the exception to have taken any steps which are likely to be productive of any good. Some of these distilleries, I think, as I said just now, were malting a large quantity of barley. They had put up retaining tanks; they must have known it was ridiculous—filter-beds close to the river. Some of the Commissioners are probably aware that some of the refuse has formed into a sort of thick slimy condition, which, instead of draining from gravel beds, as other forms of sewage pollution will, plugs up everything immediately the place gets full, and it just runs over into the river. That is all. Our complaint is that they have not taken it up earnestly. The position we wish to assert is that we want nothing more than the law gives us now, and that we are entirely opposed to any new authority being set up to deal with the question. Those were the three points upon which we are strongest. There is a letter from Sir Charles Logan, Lady Seafield's agent, who is unable to come here; and perhaps it would be as well if I read to the Commission a passage from his letter. Sir Charles Logan wrote to me, and I wrote back my views to him, and he says:—"What you propose to state to the Commissioners appears to me quite the right way of laying before them the views of the fishing proprietors." And he says:—"That it should be brought clearly out that the distillers have no right or reason for posing as martyrs who have been hardly treated, but that for years past efforts have been made to induce them to adopt remedial measures—which they have obstinately resisted—and it is only now, when they find that the law is against them, that they are seriously and honestly facing the difficulties and realising that they must take some steps to remedy the evil or must take the consequences." Well, that is from Sir Charles Logan's letter, who is Lady Seafield's representative, and she is, I daresay many of the Commissioners are aware, one of the chief proprietors in Scotland. She owns a large property on the Spey. If there are any other points upon which the Commission would like any other information, I should be happy to give it.

20002. (*Colonel Harding.*) I should like to ask one or two questions. You referred to the wonderful expansion of this industry in the district of the Spey?—Yes.

20003. Can you tell us what is the cause of that industry being there localised and so largely increased?—Well, conditions, of course, affect it; you know how industries do increase. Now, for instance, if you look at the town of Kirkcaldy, it is wholly given up to the manufacture of oil-cloth and linoleum. Now, there is nothing special about the town of Kirkcaldy which is favourable to the manufacture of linoleum, but I think you will find that, given water is good for making whisky, the distillers will always come down and get that water, because, mind you, it is not every water that will make whisky.

20004. Then it may be due largely or partly to the special quality of the water in that district?—Quite so; there is one distillery which possibly some of you may have seen on the Highland line up near Dalwhinnie. It is not working; they spent a lot of money building it, and I have asked why nothing was doing there, and I was told that the reason why it was shut down was that they had found that the water was unsuitable for making whisky, and I think that in all probability the reason for the distilleries having congregated on the Spey side is that the water in that part of the country is more suitable for making whisky than in other places. And Mr. Findlay has reminded me there is a trade reason for it. Glenlivet was what you might almost call the pioneer of distilleries, and Glenlivet whisky had a very important name in the market. It was a guarantee of goodness, and a large number of these distilleries having come into that district, now also attach to the name of their own distillery the word "Glenlivet." It enhances the value of the product that they are making to be enabled to get the mantle of Glenlivet thrown over them. (*Mr. Menzies.*) It is absolutely untrue; there is no Livet water in any of them.

20005. May I ask your Grace whether any of the distilleries have leased lands from yourself?—(*Duke of Richmond and Gordon.*) Leased?

20006. Yes?—There is the Glenlivet one which I succeeded to, which my father succeeded to, and which his father before him succeeded to; that was a feu. There is another one, a very old one, on the Fiddich, which we succeeded to in the same way, and I am not aware that there is any other.

20007. Then, so far as your estate is concerned, you are able to prevent the extension of distilleries by refusing to lease land or to sell it for that purpose?—Well, no; because the original feu provides a certain amount of land, and I cannot control the amount of building which the holder of the feu chooses to put up.

20008. But you can prevent the creation of new feus?—On, yes; but where I feued, say, take, for example, ten acres, a man, we will say ten or twelve years ago, only had one acre of building on that; I cannot control the amount of building he puts up on the remaining nine acres. Do you know what a feu charter is—the difference between it and a lease?

20009. I am afraid I have only a vague idea?—A feu charter is a making away with your property for all eternity for a small sum.

20010. It is equivalent to a lease?—It is interminable.

20011. It is equivalent to a 999 years' lease?—Yes, or double that. (*Mr. Menzies.*) That is it.

20012. Then, I suppose the Commission may take it that the concentration of distilleries in Glen Spey cannot have been due to the facilities with which these feus are obtainable, if we may judge at least from the exceedingly stringent conditions which Mr. Grant has referred to?—(*Mr. Grant.*) I can also offer you another reason; there were many, many more distilleries 50 years ago on the Livet and the Spey than 20 years ago, because, along with many farms, there were small distilleries attached all over the country, and the reason of the origin and the growth of a lot of the present large distilleries was simply because by the amalgamation of one interest with another, one disappeared and another started on; and if Sir George Macpherson Grant were here to-day, he would tell you that these small places really used to be let along with the farms. It was not a distillery and a farm; it was a farm and a distillery, and in many cases, what was formerly a very small concern, has now grown up into one of these big places.

20013. Do not all these distilleries represent a very large capital value, and may we not take it that these distilleries have a value locally in promoting the agriculture of the district?—(*Duke of Richmond and Gordon.*) Oh, no. Certainly not a large one.

20014. Do they exercise no influence whatever in the raising of certain crops?—(*Duke of Richmond and Gordon.*) Barley is the only crop which is required for them.

20015. Would the complete removal of the distilleries affect the agriculture of the district at all?—I do not think it would. Mind you, the distillers will only buy good barley. At the present moment Morayshire is a fine agricultural country, and it grows very fine barley, but a distiller will not think of buying a second-class barley in Morayshire for the sake of benefiting the country; if he sees he can get a better barley abroad cheaper, you do not think he is philanthropic enough to buy Morayshire barley.

20016. Then it is not the quality of the local barley which makes that district an attraction to the distillers?—No; I think it is more the water than the grain.

20017. Then there is nothing in the suggestion that there is a quality in the grain itself which causes the localising of the distilleries?—Oh, no; there is no guarantee that your whisky is made of home-grown barley. Gilbey does in one or two that he has acquired.

20018. I see in the statement Dr. Cowie made to us, and which you had before you, that he says that "this industry employs a large number of workmen, both directly and indirectly. It affords an outlet for barley and other agricultural products of the neighbourhood where the distilleries are situated, and also gives cheap cattle food," which, he goes on to say, at times is of special value. Your Grace does not seem to think that there is anything in that statement?—It is so cheap; they make a great deal more than all the cattle in Morayshire can eat.

20019. But has it not a value for cattle food?—It has a small value, but nothing excessive. If it were really a valuable cattle food, they would be able to dispose of it. (*Mr. Grant.*) It is the draff they dispose of for cattle. (*Mr. Menzies.*) What they call the draff. (*Duke of Richmond and Gordon.*) It is one of the sediments; I forget how he arrived at it. (*Mr. Findlay.*) It is what is left in the mash-tub.

20020. But the burnt ale is commonly used for cattle?—(*Mr. Grant.*) Certainly.

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20021. It has a certain value, or it would not be used?—It has a value. (*Mr. Menzies.*) It is infinitesimal. (*Duke of Richmond and Gordon.*) It has a value in one way, but not in another; it has a value to the extent that it is a good food for cattle, but it is of very little value really to the distiller, because he in many cases gives it away. He says to the farmer, "If you like to come and cart this away and give it to your cattle, you shall have it." It is not a marketable product to the distiller.

20022. Then we are to take it that in your Grace's opinion, although burnt ale is used locally for cattle food, that great industry is of no local value?—Oh, no. (*Mr. Menzies.*) If I did not have a bit of draff on my home farm, it would not make one bit of difference. (*Duke of Richmond and Gordon.*) It does not make an appreciable difference; it is a convenience. (*Mr. Menzies.*) It would cost you very little more to get something else. (*Mr. Grant.*) It is the burnt ale I was referring to.

20023. My object is rather to point out that it would be to the interests of the locality that the local landowners should assist distillers now that they are evidently showing a desire which, although not at first earnest, now certainly appears to be earnest, to solve the great difficulty which lies before them?—(*Duke of Richmond and Gordon.*) I see what you mean. (*Mr. Grant.*) Are we to suffer all this time? May I ask, are we to allow these men to go on? My own personal experience with the Daluaine case has been extremely unfortunate.

20024. Mr. Grant, would you allow me to finish my questions to the Duke? I will afterwards deal with you. In regard to the condition of the Fiddich, we were told when we visited that district last year that, although its condition some four or five years ago had been obviously bad, and at certain times the stream was covered with very considerable growth of fungus or *leptomitus*, that there had been within recent times considerable improvement in the condition of that stream, and certainly when we visited it there was no evidence of the presence of that fungus, and, though it is unlikely, perhaps, that we should have seen it at its worst, we did not see the froth floating over the surface; but we were told by persons not connected directly with the distillers that there had been a distinct improvement in the condition of the Fiddich, and I should be very much interested to know whether the Duke himself has been able to form any opinion as to whether there has been in consequence of the works which have been carried out at the Mortlach Distillery and others, any improvement at all in the stream?—(*Duke of Richmond and Gordon.*) I think there has been a slight improvement, but with regard to what you say about not seeing any fungus, I should like to point this out, that although you might not have seen any when you were there, was the river big at the time; was there a big volume of water, a spate, or anything?

20025. I am unable to say, having only seen it once, whether there was an unusual condition?—The heavy water will wash the stuff away.

20026. It was about May last year; it did not occur to me that there was any spate on. The important point which was laid before us was that whereas three or four years ago there had been very evident growth of fungus, there had not within the last year or two been any evidence of the fungus; and certainly at the time when we were there, and we inspected the stream rather carefully—we were there some time—we saw no evidence of the presence of fungus then?—Well, fungus will come and go, you see, in this way, that if you get a heavy spate you will wash a great deal of it clean away, but the moment the river drops the least, the moment the flow of water diminishes, and the effluent is being put into the river from a distillery, then your fungus comes on and on again.

20027. But, as one of my colleagues reminds me, it was rather a dry time; probably we saw the river at its worst?—Well, at the end of May very likely there was not much work going on. (*Mr. Menzies.*) The spring floods would have washed every bit of fungus away.

20028. The point I wanted to get at was, whether the work carried out at Dr. Cowie's distillery, where a serious effort had been made to meet the difficulty, and where a very evident improvement has been brought about with the effluent produced, as compared with the very foul matter turned out of the distillery, whether those efforts have led to any improvement in the stream?—(*Duke of Richmond and Gordon.*) I think Dr. Cowie's was a *bonâ-fide* effort, but it failed so absolutely, that only since the 1st January—I have not the exact date by me—we took a sample of the effluent from Dr. Cowie's distillery, and we sent it up to Edinburgh to be analysed.

20029. When was that?—That was since January; I think it was in the month of February.

20030. This year?—This year. We sent it up to Edinburgh to be analysed, and the report of the analyst was that it was the worst form of pollution that we had hitherto submitted to him. I can get the report, and if the Commission would like it I would send it on to you.

20031. But is it suggested that the effluent which was then analysed was worse than any sample of crude matter turned out from the distillery that had been submitted for analysis?—I think it was as bad, if not worse, than any that they had ever had.

20032. Was it really suggested that no improvement had been brought about in the burnt ale by the treatment which was given to it?—Dr. Cowie's first attempt was with bacteria beds. Well, they appeared to promise well, but the bacteria beds got choked, and I think he would tell you himself that he is now satisfied that the bacteria bed is a failure for the purification.

20033. I did not gather from his evidence that that was his opinion. I think he did tell us that bacteria beds alone, he thought, would be somewhat likely to choke, but he has introduced other processes, certain treatment by lime, I believe, and a subsequent treatment after the contact beds by a percolating filter, which, we gathered, were rather promising in their results?—Yes; what I meant was this: I think that the first attempt Dr. Cowie made was with bacteria beds pure and simple. (*Mr. Findlay.*) So I understood.

20034. That did not seem to bring about a satisfactory improvement?—(*Duke of Richmond and Gordon.*) No.

20035. There was improvement, but not sufficient improvement?—No; and they got choked in a very short time.

20036. Since then, we understand Dr. Cowie has been settling the solids as much as possible, and treating with lime, and he now finds a very considerable improvement?—I have not taken a sample from Dr. Cowie's distillery quite recently, but I should like the Commission to read the report I have just referred to.

20037. Then your Grace is quite unable to express an opinion as to whether there has or has not been any improvement in the condition of the Fiddich within, say, the last few years?—I would rather ask you to put that question to Mr. Menzies, whose house is within a mile of where the Fiddich runs into the Spey. (*Mr. Menzies.*) I should only say the Fiddich has never been in a worse condition, owing to the distilleries letting out their tanks, than it has been this spring. Many of my own tenants can prove it. Nothing has been done to improve it, and the Fiddich has never been in a worse condition, or the water down below. That is simply because—not Dr. Cowie, who is the one man in Dufftown who has really done his best, in my opinion, but others have let out their tanks every week.

20038. May I put this to you in another way: Is the condition of the Fiddich below Dr. Cowie's distillery in any way improved by the work that he has carried on?—I see no improvement at all. I do not know his distillery from the others.

20039. The work hitherto carried out by Dr. Cowie is useless?—There has been no improvement in the Fiddich this spring. I have lived there these 30 years, and, as to the salmon spawning, I can only corroborate his Grace in what he has said, that no fish have been able to spawn in the Fiddich for some years since the distilleries became so numerous.

20040. These distilleries' feus must be of considerable value to you?—(*Mr. Grant.*) Yes; well, that, of course, is a private question.

20041. I do not want to press that, but merely to get the general fact that they are of a certain value, that the destruction of that industry on your estate is perhaps not desirable?—I cannot express an opinion as regards the destruction of distilleries, because I hold that, personally, I have always taken an extremely lenient line in dealing with them.

20042. Are the conditions you referred to in all your feu charters?—No, I cannot say that they are in the feu charters that I have got on the distilleries that I succeeded to from my father and my grandfather; I can-

not put in stringent clauses in them, but, mind you, when my father feued the Daluaine Distillery to the Daluaine Company it was a little tiny building attached to the farm, and directly they got that feu, and he died, and I succeeded, they began to build, and they have been building practically ever since. Nobody could conceive, at the time they got that feu, that the distillery would be so largely developed, as they had at first a very small distillery.

20043. The industry has developed?—As his Grace has said, you cannot control building.

20044. I think you said that one of the conditions of the charters was that, not only should the quantity of water which left the stream be put back into the stream, but that it should be the same quality when it was returned to the stream?—I referred to that; I did not know that it was necessary to put that into the charter; I understand that is the law of the land.

20045. Would that, in your view, prevent the evaporation of burnt ale?—I may say, speaking generally, without committing myself, as regards this question, that I have really been rather fortunate, I think, in my own dealings with distilleries on my own property, because though we have got an action against the Daluaine Company, speaking absolutely personally, I must say that the Tamdhu directors, and also the directors of Cardow, have informed me that they have spent considerable sums, but I will not commit myself to say whether this is right or wrong.

20046. You mean that you express no opinion on the question whether the expenditure has been wise or otherwise?—Yes; but I will not deny, because it would be absurd to say, that they have not done anything, these two companies, because they have spent considerable sums of money.

20047. We have been told that they have both spent considerable sums?—I do not doubt it. It does not alter my decision if they pollute the river. Because they have spent considerable sums, they have both made considerable profit, and though they have spent this money, they must keep the law.

20048. What strikes me, as a Commissioner, I may say, is this, that the position that is taken up by yourself and other landowners seems justifiable enough, in view of the complete unwillingness of many of these distillers to do anything for many years, in view of their turning out the most foul effluent into streams, and apparently not recognising any duties to purify their effluent. But at the present moment, when very evident efforts are being made by distillers, and when considerable sums are being expended by them to solve their difficulty, one cannot but feel that a certain amount of patience on the part of the landowners, and a certain amount of assistance on the part of the landowners, might bring about a very great improvement; is it not possible?—I think the only answer I should suggest to you is this, if you are going to be very much more patient with some of them, we will lose our prescriptive rights. (*Mr. Menzies.*) You cannot do that; you cannot lose prescriptive rights. (*Mr. Grant.*) If we go on being tolerant for ever, will it become a right? (*Mr. Menzies.*) The Rivers Pollution Act would stop that.

20049. There is evidently an effort being made to solve the difficulty, and they have appealed to this Commission to investigate the matter, and they have expressed a general readiness to carry out works which may be suggested, and so forth, and there does seem a prospect of this great difficulty being solved, not to the point, possibly, of restoring the water to absolute purity again, but of restoring it to such a point that the stream itself would readily oxidise the remaining impurities, and so therefore you might consider the effluent to be innocuous (*Mr. Findlay.*) Migh I remind you, Colonel Harding, that in 1901 there was a form of agreement submitted to the distilleries by which they got a year's grace, during which no proceedings were taken whatever, to take steps, and the experience of the proprietors of that year was not very encouraging. We have been giving time all along.

20050. I may say that I am Chairman of a Rivers Board in Yorkshire, where we have to deal with countless pollutions, and we earnestly hope that your beautiful Spey stream may not become like one of our streams, but we have there the same difficulty with manufacturers, and we get very many promises and very little performances. But where we do find a manufacturer who is striving with his difficulty we find it policy to assist him in any way we can?—Unfortunately, some of them will not strive. There are one or two who are working hard, but we have got 27 people to deal with, and the question is, what position are we to adopt with regard to, say, the other 20? If you have seven making experiments, are the other 20 to be allowed to continue to pour all their burnt ale into the stream?

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20051. There is just this difficulty, you see, that this question is at present in a transitional state; it is in the experimental stage, and I daresay the 20 are watching what the few are doing, with the idea of adopting some process pronounced to be successful?—Well, there is no doubt by the persistent pressure that we have brought to bear upon them during the last 15 years the whole 27 are very much more careful. I do not say they are as careful as they should be, but they are very much more careful than they were. (*Mr. Menzies.*) They are very careful to put it in at night. That is all they are careful to do.

20052. The last question with which I will trouble the deputation is this: I should like to ask the view of the Duke of Richmond upon the statement made to this Commission by Mr. Grant—not the Mr. Grant present to-day, but Mr. Grant who said he was at once a distiller and a fisherman, and his experience warranted him in saying that the fishing was at least as good now in that part of the river, where he fished near his distillery, as it was any time before there was a distillery?—(*Duke of Richmond and Gordon.*) What is that particular statement?

20053. In the statement which I think your Grace has had before you?—What number was it?

20054. I will refer you to the particular page. "(Mr. Grant.) I have fished the Spey for 46 years steadily every year, and in my opinion the effluents that are going into the river do not in any way hinder sport—not in the slightest. I have had experience; my father had the fishing below where this Daluaine Distillery is for 21 years; I fished it during his lifetime, and I had it for five years myself immediately below where the Daluaine Distillery effluents were going into the river. I have seen the burnt ale coming into the top pool, and it ran down the side, but in the second pool the water ran to the side, and consequently the whole of that pool the burnt ale was distributed right over it, and I have killed many and many a hundred salmon in that pool when that effluent has been going down.

"Do you suggest to us that pot ale is an excellent thing for improving the condition of the river for fisheries?—I do not say that it is an excellent thing for improving the condition of the river, but it does not hinder sport." Then Sir Michael Foster asked him, "Not only now does it not injure sport, but it has not done so in past years?" and he says, "Certainly not." Well, that merely shows that the statement that the Spey has been very gravely injured by these effluents is not acknowledged by everyone?—When I read this answer of Mr. Grant's, No. 19737, I was amazed that anybody who had ever had a fishing rod in his hand, and had gone down to the banks of the Spey, should have the temerity to make such a statement as that. You must remember that he is a very big distiller, the very biggest distiller on the Spey; he could hardly talk otherwise. (*Mr. Findlay.*) With regard to his statement as to the water immediately below the Daluaine Distillery, Mr. Grant has not fished that water for 20 years. (*Mr. Menzies.*) More than 20 years. (*Mr. Findlay.*) More than 20 years, and the top pool below the Daluaine Distillery has been so filthy, that for many years it was quite impossible to fish it, so Mr. Grant's experience of this particular water is 25 years old.

20055. (*Chairman.*) May I ask you whether, having regard to the fact that some of the distillers are taking action for improvement, you see any reason to hope that they will be able to do it efficiently?—(*Duke of Richmond and Gordon.*) I would not confine the distillers who are taking action to any definite number of seven or less; I think they are all doing something, and they have evidently all the sense to see that something needs to be done, but whether they are all doing enough is another question. Then I understand your Lordship wishes to ask me——

20056. I wanted to know whether you could see any signs of improvement?—Oh, certainly: I think there are indications that the stuff can be satisfactorily dealt with, and may be satisfactorily dealt with. I do not believe all our labour during these last 10 years has

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been absolutely in vain; I believe they are getting nearer their means of purification.

20057. Because, of course, the analyses that you got of Dr. Cowie's effluent from Edinburgh must have been very discouraging, but I take it that the analyses which our own chemist, Dr. McGowan made, would be of an encouraging character?—(*Dr. McGowan.*) Yes the first was very good indeed, and the second. (*Mr. Findlay.*) Well, I think I may explain, with regard to that, that the analyses to which his Grace referred was before the introduction of this precipitation process. I think since then results have been more satisfactory. (*Dr. McGowan.*) I rather think it was before he put on the circular filter—the continuation filter. (*Colonel Harding.*) That you got a good sample? (*Dr. McGowan.*) It was after that I got them; it was immediately improved after that. That was going in January, so presumably your Grace had the sample before then? (*Duke of Richmond and Gordon.*) I could send the Commission the date. I do not wish to misrepresent anything. If the Commission wish that document I could send it to the Secretary.

20058. (*Colonel Harding.*) The Commission, I think, would be anxious that experiments with bacteria beds should not be discouraged by the impression being carried away that they were quite worthless because the analyses which our own experts have carried out were somewhat encouraging. But there can be no doubt—I think Dr. Cowie himself will agree to it—that the bacteria beds as at first installed, and without antecedent precipitation and lime, were not of great value. There was an improvement, but not sufficient. (*Mr. Findlay.*) Another unfortunate circumstance is this, that the proprietors had no indication of the extent to which the distillers used these things. I mean they may put in a sample and treat it from day to day, and then produce a very fair effluent at the end, but we have no indication that the capacity of the beds is sufficient to deal with the whole of their waste products.

20059. I should like to ask the Duke of Richmond an important question, and it is this, that inasmuch as the Commission is investigating through its own experts very carefully not only the experiments that are being carried out by land treatment and by evaporation, but those which are being carried out by bacterial methods, whether it would not be possible in some way for the riparian owners to stay their hands for a certain period in order to give time for the distillers to find out exactly what is the best way of dealing with these matters. Quite a large number of experiments are being carried out. They are being carried out with every readiness to place them under our supervision; they are being supervised by us; we ourselves shall form an opinion upon them, and report upon them, and in those circumstances is it quite wise or generous to press the distillers until a certain time has been given to find out these results?—(*Duke of Richmond and Gordon.*) I do not think I could give that pledge. (*Mr. Menzies.*) I should have thought nine years was about enough for most people. (*Duke of Richmond and Gordon.*) I have no idea when this Commission is going to report, and assuming that this Commission did report in a direction favourable to us, I am then quite ignorant as to what length of time would elapse before legislation would ensue on the subject. I could not on behalf of the other proprietors give a pledge to take it lying down for another seven years as we have done for the last seven.

20060. (*Chairman.*) Of course, this scientific inquiry is very slow, and I am afraid we should hardly be able to begin this, Dr. Houston, for another year?—(*Dr. Houston.*) I should not think so.

20061. (*Chairman.*) What you have got in hand will take you, roughly speaking, a year?—I think Dr. McGowan will tell you. (*Dr. McGowan.*) I should think fully a year.

20062. But in the meantime the distillers are, at any rate, making some experiments?—Well, Dr. Cowie is the only one with whom I have communicated.

20063. But, at all events, the distillers have expressed their readiness to carry on experiments and to take any advice; in fact, to carry out any experiments that our experience will lead us to suggest to them.

(*Secretary.*) Yes, they have informed the Commission of their willingness to do this; their position rather is that they do not want to be spending money on what may turn out to be useless. For instance, that evaporating process, which has been referred to as "the best of all," is very costly, and there are some reasons for thinking that it is not as satisfactory as it has been supposed to be. (*Duke of Richmond and Gordon.*) Well, I think the Commission will see that we have not been unreasonable in the past, and I think they might trust us not to be unreasonable in the future, but I must decline to give any guarantee as to the particular course of action we may find it necessary to take.

20064. (*Chairman.*) I should not like to ask you to pledge yourself?—That was rather what Col. Harding asked.

20065. (*Colonel Harding.*) I scarcely asked for a guarantee or a pledge, or even for a promise; all that I wanted to ascertain was whether there would be a willingness on the part of the landlords in view of the earnestness with which the matter is now being taken up by distillers, and in view of the fact that we are watching those experiments, to hold their hands, to allow time?—(*Mr. Menzies.*) We do not allow that willingness; that is the only thing.

20066. We quite admit the position the landowners take up is justified by the refusal of these distillers for many years to do anything, and justified by their statement in some cases that they had a perfect right to pollute the stream, a statement with which, as chairman of the Rivers Board, I am quite familiar?—Which most of them still think.

20067. But the position of affairs has very considerably changed within the last few months?—Meanwhile, if we give them another four years, all leases to fall in will be down half in rent.

20068. Some of our experts who were over there recently do not appear to have been struck with any foul condition of the streams when they were there. I see that they say—I suppose this is the Fiddich—"We inspected the river for several hundred yards immediately below the town, and also a long reach about a mile below the town, and found it apparently free from any serious pollution." And in another paragraph they say:—"The river and streams into which the effluents flow seemed to be clean and in good condition"?—That was not a fair time of the year. (*Duke of Richmond and Gordon.*) But might I ask this question: were those samples of the river taken on days when the effluent was coming from the distillery?

20069. This is a general observation?—If you were to go to-day below a certain distillery you might find nothing, because the waste products from the whisky making are going into the tank, but to-morrow he lets his tank go, and you will find a totally different state of things.

20070. One quite appreciates, of course, the feeling of large landowners that this condition of things must not be allowed to get worse?—I do not want to suggest that the distillers are always trying to cheat us; I do not go so far as that; but unless you are aware of the conditions of work going on at a distillery when a sample is taken from a river below that distillery, it is valueless, because to-day it is good; to-morrow it is bad. (*Mr. Menzies.*) You must live on the banks to know anything about it.

SEVENTIETH DAY.

Thursday, 8th December, 1904.

PRESENT:

Colonel T. W. Harding, J.P., D.L., in the Chair. | Major-General Constantine Phipps Carey, C.B., R.E.
Mr. W. H. Power, C.B., F.R.S. | Mr. T. J. Stafford, F.R.C.S.I.

Mr. F. J. Willis, *Secretary*.

ALSO PRESENT:

Dr. A. C. Houston. | Dr. George McGowan.

Mr. Herbert Hughes, C.M.G., called in; and Examined

20071. (*Chairman.*) Mr. Herbert Hughes, you are, and have been for many years, the Clerk of the Mill-owners' Association of the River Don?—Yes.

20072. Would you be good enough to explain to us what part of the River Don that covers?—The whole of it to the boundary of Sheffield.

20073. That does not include Rotherham?—No, it does not include Rotherham.

20074. We have heard of the Don as a very polluted stream, but that description would be applicable rather below than above Sheffield?—Yes.

20075. Above Sheffield, I take it, the Don is fairly pure, is it not?—Yes, reasonably pure.

20076. (*Mr. Power.*) Do they catch fish in the Don, in that portion of the river?—No, I doubt it; there may be fish in it, of course; but it is not a river that you would resort to for that purpose.

20077. (*Chairman.*) But there are a few mills in the Don above Sheffield?—There are a good many mills on the Don above Sheffield, and on its tributaries.

20078. How many mills—six, eight, ten?—Oh, more.

20079. How soon do manufactories appear on the Don?—Well, the highest up is at Thurlestone.

20080. Is that much above Sheffield?—About 15 miles above Sheffield.

20081. Then most of your manufactories, I assume, use their mill dams for the purpose of power producing?—Only power.

20082. They are not manufactories turning out trade effluents at all?—With one exception on the Don; that is a paper mill, and there are one or two wire works which may possibly turn some acid into the stream.

20083. Which is the first dam you have on the stream?—Bullhouse Mill, Thurlestone.

20084. Is that the one which formed the subject of recent legal proceedings?—Yes.

20085. Well, the questions that I would put to you, Mr. Hughes, would be on two points, namely, first, as to whether dam sludging did cause inconvenience or nuisance; and, secondly, as to whether the modification of the law, with a view to preventing dam sludging, would seriously affect the manufactories of your Association; and whether there is not some alternative to the present methods of sludging which would be less objectionable than the present ones are alleged to be. Now, first of all, on the question of pollution, I may take it, I suppose, that it depends on the character of the stream itself?—Everything.

20086. Whether the stream is a polluted stream or is a stream of fairly fresh water?—Everything depends upon it.

20087. Therefore the evils of dam sludging would be necessarily very much greater in a polluted than in a pure stream?—Yes; a dam can only receive what comes to it down a stream, and the consequence is that if preventable pollution is permitted—and especially riparian pollution—some of the results of that will come into the mill dam; if, on the other hand, you could imagine a stream in which there were absolutely no riparian pollution, then it follows as the night the day that there could be no polluting matter from the dams.

20088. Well, not quite necessarily, because the upholding of the suspended matter found in a fairly pure stream would involve some putrefaction, though possibly not anything like so important putrefaction as would take place in a polluted stream?—Yes; in precisely the same way as in the natural run of a stream you get the sludging process carried out by the river, which undoubtedly might produce, and does produce, some amount of putrefaction. Of course, coming down the stream you get alluvial detritus, and you also get a certain amount of vegetable matter. Now, what does a stream do for itself, a stream like the Don, which is the only one as to which I am giving evidence to you to-day? What happens?—Upon the saddle back, the Pennine Range, as we call it, the division between the East and the West, roughly speaking, you get an enormous rainfall. Well, there comes a storm; down comes the stream heavily charged with alluvial detritus for the most part, but also, of course, with vegetable detritus. Well, what happens is this: As soon as that flood has spent its force there is a check, either from a turn in the river or from a variation in level, of all that mass of stuff, and there it remains until the next flood comes; and if the last flood was in February, and the next one is, as often happens, in the following autumn, the same putrefaction would go on there in the reaches of the river as goes on in the dams. I have no right to ask questions, only to give evidence; but what I want to ask is this: How can this sludging of the dam be reasonably objected to, if there has never been heard of a case of illness even, let alone danger to life from the effects of sludging dams? You know we have had to go—if I may use a homely expression—through the small sieve with regard to this question of sludging in recent years. You know the Rivers Board—as to whom, on ground of courtesy, we are the best of friends—told us that they intended to put in force their powers under their Act—I dare say you have had that brought before you, the 57 and 58 Victoria. They intended to stop dam sludging, because they said that even having regard to the saving clause which makes it no offence "to put, or permit to be carried, into any stream any sand or gravel or natural deposit——"

20089. Natural?—"Natural deposit which shall have flowed from or been deposited by the current of any such river or stream: provided that the sand or gravel or other natural deposit so put back or carried as aforesaid do not interfere with the due flow of or pollute the waters of such river or stream." Dam sludging was an offence. They said: "Under that we were going to try the question of dam sludging, because we are content that it both interferes with the flow of and pollutes the river." Well, that was, so to speak, if somewhat hostile, nevertheless done in a friendly way; and we agreed that we would take this Bullhouse dam and we would sludge it in front of everybody interested.

20090. The Bullhouse dam being the first dam on the stream?—The first on the stream, and we would try this put by the evidence of what they had seen during the process of sludging; and, accordingly, on a given day, notice having been given, we proceeded to sludge our dam, which had not been sludged for 12 months before. It was done in the ordinary way; I do not know whether you have had any evidence as to how it is done; you

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simply let the water run through the dam and you loose the masses of sand and detritus, and it goes on down the river in the ordinary way. Well, now, we had that dam sludging, and we had many eminent gentlemen there who both examined the process, took samples of the effluent, and generally instructed themselves as to what happened during the process of sludging. Following that, which we expected, of course, was a summons before the West Riding County Bench, Barnsley, for interfering with the flow of and polluting the stream. Of course, the form of the thing was for putting solid matter in the stream, and we, of course, urged that our exemption covered what we did. They said: "No; you both interfere with the flow of, and you pollute, the stream." Well, evidence was taken there, and the magistrates dismissed the case. Evidence was taken again before the County Bench in the Quarter Sessions. There were a great many magistrates present, but I do not know that that mattered very much. What does matter very much is that the West Riding Rivers Board used—perfectly legitimately and fairly, but nevertheless did use—every means in their power to prove that this sludging would interfere with the flow of, and pollute, the river, the bulk of the evidence being given on pollution. I can tell you what a strong case was attempted to be made against us by telling you that they fetched Sir Frederick Bramwell down to give evidence on the subject, and he gave lengthy evidence, the result being that the case was dismissed again. Then under this special Act of theirs, the defendant being a public body, could appeal to the Divisional Court. They did so appeal, and the case was argued before Mr. Justice Wills and Mr. Justice Kennedy. At the end of this lengthened argument, unfortunately, one of these little judicial difficulties arose which do arise in these cases. The two learned Judges had some doubt as to whether they were able to deal with the facts; whether the appeal to them was not one purely of law. In that case, of course, they would have had to dismiss the case again, because the facts had been ascertained and adjudicated upon by the Courts of Quarter and Petty Sessions. When they had come to the conclusion that they could hear an appeal on the question of fact, it turned out that owing to Assize work and illness the Court could not be reconstituted, so we had to begin *de novo*, and we argued the whole case out on law and on fact, and the case on behalf of the Rivers Board was argued by no less able a person than Mr. Tindall Atkinson, who, you may depend upon it, made the most of his case, as he always does. The Court dismissed it again on the ground, which is the important one, if you will allow me to say so, from your point of view, that this sludging of the dam did not interfere with the flow of and did not pollute the river.

20091. Then that was the conclusion, Mr. Hughes, in connection with the sludging of the dam, which was the first on the pure stream?—Yes; but that was taken voluntarily by both sides, because obviously what we wanted to get at was a reasonably fair trial. What they wanted to find out was whether the sludge in itself interfered with the flow of or polluted the river. They knew perfectly well, of course, that lower down the stream there had been many preventable cases of pollution, but it would not be fair for them because there were preventable cases of pollution, which, up to that time, they had not stopped, to urge those cases of pollution against us, because we had never done anything to contribute to them. If they would keep the river pure, then, except for the point which you made, which I have endeavoured to deal with, that is, that matter remaining in the milldam may give rise to some amount of putrefaction (very small, by the way, but may give rise to some putrefaction)—except for that point, if they make the stream clear there would be no question of pollution.

20092. This particular case, Mr. Hughes, does not appear to have been a very strong one; it is a question as to whether the Rivers Board have been well advised in selecting it; because the matters which were settling, which were held back, were matters coming down naturally in an unpolluted stream. You would agree, would you not, that very serious pollution would arise by the holding up of putrescible matters, say, from sewage?—Yes.

20093. Holding these up for months, for a year, or two, before they are discharged wholesale into a stream?—I follow you exactly, but look at the hardship. We will suppose, for a moment that the Rivers Board or other public authority is going to prevent all preventable causes of pollution. Very well, they say during the time that we have not exercised our powers fully, or have not achieved our end, pollution will go into your dams and therefore you shall not sludge. Time goes on and the river has had removed from it all preventable causes of pollution; and you have stopped a harmless process; you have interfered with trade. Why? Because, for a time, the Board or the competent authority, whoever it may be, has not removed the pollution out of the river; in other words, it is the story of the wolf and the lamb exactly.

20094. I am pleased to find that you have a lively faith in the ultimate purification of streams, Mr. Hughes?—As to that, Mr. Chairman, all I can tell you is this: Granted—and I grant it most fully, and so does every gentleman forming this millowners' body; I will tell you why I say that with a confident belief in what I am saying in a moment—granted we all say we want pollution stopped; are wholly in favour of pollution being stopped; but what we also say is this: With regard to a manufacturing river, a river running through a manufacturing district, what is the objective, the end, the aim, of those who desire to make that pure? Is it that they desire, as one of the hon. Commissioners suggested to me a minute ago, talking about fish, that we are going to see entirely removed all causes of pollution in the River Don; that the salmon pastures of Sheffield are again to become salmon pastures? If that is the desire, I do not hesitate to say, as a man of business and as a man of common sense, that it will never be done. The river is the natural adjunct to a manufacturing place. It goes down to Rotherham; it goes down to Doncaster, and then it goes to the sea, without the slightest bit of harm or difference to anybody, whether it is polluted by manufacturing processes or whether it is not.

20095. You say the river is the adjunct to the manufacturing process of a district?—Undoubtedly that river, the River Don, has been one of the causes of Sheffield rising from a little manufacturing village, where a few knives were made, into the great manufacturing place which it is to-day.

20096. But you do not suggest, do you, that the increasing impurity of the river can be an advantage to manufacturers?—I do not say that for a moment, Sir, although I am not going to make it really a strong argument or anything of that kind; but, as a matter of fact—I should almost say it has been a fact, and it is an undoubted fact, that since we took the sewage out of the River Don at Sheffield—quite the proper thing to do, of course—the water plays havoc with the boilers. The acids in the river were neutralised by the alkalies of the sewage actually; and as matter of fact, from the manufacturing point of view, the boilers, beyond the fact that they took some cleaning, did not get bitten and pitted with the acid as they do to-day; and anybody in Sheffield to-day would tell you that the life of a boiler since the sewage was out of the river was less than it was before. But let me go back to the actual evidence; that is only in passing. Take, Mr. Chairman, an ordinary case of an ordinary firm which does not pollute; take Vickers, Sons, and Maxim, or any firm you like in Sheffield who carries on manufacturing processes; what use do they make of the river? If they are upon the river they take the water in; they use it in their boilers for raising steam, and when they have done with it they put it back.

20097. They probably use it for condensing also; do they use it for condensing purposes?—And for condensing, too. When they put that water back into the stream; is it the same water as it went in; is it water that fish will live in? It cannot be; it must of necessity, by reason of the introduction of oil and other things in the water running the boilers—it must of necessity become less pure and less suitable for fish to live in. But which is to survive—the manufacturer, who is giving employment to thousands, the manufacturer who is making England what it is, or are we to go back and make the Don a river in which fish, we will say, will exist from the one end to the other, and the manufacturers on the stream are unable to use it for the purpose of manufacturing?

20098. The point you raise is a very interesting one, but it is somewhat broad and a little way from the special point we are dealing with to-day?—I quite agree.

20099. The special point we are dealing with to-day, and upon which we are anxious to obtain information from you is, first of all, whether any nuisance does, in fact, arise from the sludging of milldams. Now, you are

able, I believe, only to give us information in regard to the sludging of milldams upon an unpolluted or substantially unpolluted stream?—Substantially unpolluted stream, yes.

20100. And you give us as your opinion that no nuisance arises; and that, in point of fact, in your view, no inconvenience arises?—Yes.

20101. But I would like to put this, at all events, to you—you may be in the main right on an unpolluted stream, but I would like to put this to you—that the action of your manufacturers in upholding the waters of such a stream gives as a result: the sending out into such a stream of a large accumulation of suspended matter, which, if it was allowed to go minute by minute, hour by hour, day by day, would not be felt. For instance, it is likely that the suspended matter in that city would not exceed two parts per 100,000 in the natural conditions, except at times of storm. I have in my mind figures in connection with other rivers, not the Don; but it is exceedingly likely that, in times of sludging, the river would for some hours afterwards contain 100 times as much suspended matter?—Just as it does in flood, you know.

20102. It is suggested to us, if it is perfectly innocuous mineral suspended matter, sand, and so on, it will settle in the channel of a stream and only very slowly be washed away; and that the retention even of dead leaves and matters which come down the stream will cause an excess of a nuisance, which possibly might exist in theory, if they went down the stream minute by minute and hour by hour?—I do not think that it is anything like a correct view of what happens in a stream like the Don, to say that it goes down minute by minute and hour by hour, because it does not. The Don is really a mountain torrent. When you say a mountain torrent, you think of something with very high mountains and a very rapid river; but, nevertheless, it is in effect a mountain stream, a mountain torrent. What happens there is this: that the flood takes the stuff down, sewage or whatever it may be, and when it comes to some bend in the river, and the flood is exhausting its power, down goes the material in precipitation, and in the summer, in the dry time, the river itself has practically no flow excepting compensation water from the dams from the waterworks.

20103. Then I gather from what you say that this stream is not so pure as I thought it was; you say it contains sewage?—I was taking sewage; I was coming to this point, that if you take the sewage out, which *ex concessis* must be done, then your cause of offence against the dam is gone; and that brings me back to a thing I was going to say to you about a minute or two ago, except as to the question of decaying vegetable matter, the volume of decaying vegetable matter, as compared with the solid detritus, sand and gravel which comes down the stream, is practically infinitesimal.

20104. And then in your case, speaking generally, the evils of dam sludging are not great?—I do not think so at all; you know, all the way down to the lowest of our works, that is to the bottom of Sheffield, there is no sewage comes in except from certain little rural collections of houses, which are always such a difficulty; you have a certain amount of sewage percolating into the stream. Well, now, in our case that was brought as a possibility of pollution, and, of course, one after the other proved it on our opponent's side, but it was like talking about putting a wineglassful into a big bath, or something of that sort. I mean the thing was too infinitesimal to have any real effect. Below us, of course, there is the problem of the Sheffield sewage effluent, which is giving rise to a great deal of trouble and anxiety to the Sheffield Corporation at the present time.

20105. Then you have no cases of dams on very polluted streams?—No, and I do not like generalising from insufficient knowledge.

20106. The point I want to make is this, that your evidence applies to an unpolluted stream?—Practically.

20107. And that you state your opinion that in such a case the sludging of a dam would probably produce no appreciable nuisance?—It does not, in my opinion.

20108. But you do not want to convey, surely, that in any case dam sludging would give rise to no appreciable nuisance?—No, I do not. I say it is not only my opinion, because we have been, as I say, through the sworn testimony in three Courts. Take the last Court, which was careful enough, the Divisional Court, that examined the matter very carefully; it is all down on sworn testimony that there has been no pollution. But take your case of a river which is polluted with sewage; just let us suppose for a moment that there was a large town at the top of the Don delivering large masses of crude sewage into the stream, would anyone think it would be a fair thing to impute to the process of sludging the fact that the pollution went on down the river at each sludging? Surely the answer would be:—Remove the source of the evil above; take the sewage out of the stream, as you have ample powers to do, and then there would be no sewage in the dams.

20109. Yes, but the whole thing would turn on this, would it not, whether—by withholding these matters and letting them accumulate for months, and it may be for a year or two years, and then turning them out wholesale within a few hours into the stream—you are not condensing the nuisance into a very short period, which, allowed to spread over the whole period, would scarcely have been appreciable?—Well, you are asking me, of course, now about something which I have no means of measuring. Just suppose for a moment that Sheffield was sending the whole of its crude sewage into the river Don and passing it down through Rotherham, and that in between the two places there was a mill dam, and that that mill dam was sludged at intervals of a year. Well, I should say that it would make no appreciable difference whatever. I should say that the nuisance of the crude sewage in that stream going down was the real nuisance, and the fact that you sent a few hundred tons or so of material, some of which was sewage, down that stream would not have any real effect in adding to the real difficulty, which would be the passing of the crude sewage of Sheffield in this stream going down to Rotherham.

20110. We take that as your opinion; but you are probably aware, are you not, that grave complaints have been repeatedly made, say, to the West Riding Authority, which you have referred to, in connection with the evils of dam sludging; that the matter has received attention in other parts of the country; that papers have been read at Sanitary Institutes calling attention to the serious evils caused by these things. You are probably aware that there is another side to the question?—I am quite aware that there is another side to the question; but, of course, I am here to answer for the river Don. I do not know what would be the effect of sludging a mill dam in a comparatively still water; but then, on the other hand, I fancy that the conditions of the river Don would apply in the case of other rivers, because from the nature of the things you cannot have these mill dams supplying power on any streams except rapid streams.

20111. Then we are to take it, reiterating what we have been talking about for some time, that in connection with this stream, which is substantially a pure stream, in connection with works which themselves do not turn out trade effluents, for the most part no serious evil, in your opinion, arises from the sludging of the dams?—No.

20112. Then the next question comes, suppose there was an alteration of the law brought about to put under the control of Rivers Boards, or other authorities, the sludging of these dams, would that, do you think, be considered to be an evil by your association; would it hurt them to any important extent if they were obliged to let off those dams at certain periods to be selected, or at times of storm, or times of holidays, and so on?—Would you kindly look at this, which I will hand in. (Document handed in.) I mentioned in my proof I would hand it in.

20113. These are regulations by your association?—These are rules as to sludging out of dams adopted at a general meeting of the Don millowners, held at the Cutlers' Hall, on Tuesday, 29th June, 1898.

20114. Then your association has imposed upon its members conditions?—Our association has imposed upon its members voluntarily conditions which were considered to be reasonable in connection with the sludging of dams.

20115. Your association already recognise that in connection with dam-sludging if certain conditions are not fulfilled evils may arise?—Yes; but I rather think, if you will allow me to say so, that the question to which we addressed ourselves was not the question of pollution, which practically, in my opinion, does

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not exist, but it was to the effect with regard to a large mass of solid matter interfering with the flow of the stream. Supposing a man, for example, did not sludge out his dam for five, six, seven, or eight years, and then sludged it out, it would stand to reason that there would be an enormous mass of materials to go down; and not only would he affect the stream by sending an enormous amount of solid matter in suspension down, but he also would affect every other millowner below him whose shuttles would be open. They would know nothing about when he was going to do it; their shuttles would be open, and in would go this mass of material, and the thing would have to be done three or four times over, which would be a wrong thing. The consequence was we put ourselves into the voluntary harness in order to insure reasonable protection. For instance:—

1.—All dams upon the streams should be cleaned out every year.

2.—The time for sludging out dams should, if possible, be during holidays or general stoppages; but no dam should be sludged unless there is a good flow of water in the main stream."

The object of that, of course, being partly to prevent the other dams being made receptacles of the sludging of the first, which would be to do the work three or four times over—well, 30 times over if it went all down the stream; and on the other hand on the part of the public that there should be a good flow of water on the stream, so that it should not be clogged up by solid matter:—

3.—As much water as possible should be passed through the dam at the time of sludging, so as to carry it away rapidly and in as fine particles as possible, and the work, when once commenced, should be carried out expeditiously.

4.—Information must be conveyed 48 hours before sludging a dam to all the millowners down the stream within a distance of five miles, and to the manager of the River Don Navigation, Corn Exchange Buildings, Sheffield.

That is because they have an intake in the dam for the purposes of their canal. Of course, they are in the same position as an ordinary millowner; they do not want their shuttles open when material is going down, because they would have to clear it out again.

5.—In case these rules are not generally adhered to by any millowner, he shall not be entitled to be defended out of the funds of the millowners in case a summons is issued against him for sludging his dam.

Well, now, we put ourselves in that position. Now let me answer your question. Any regulations in reason as to how dams should be sludged will be cheerfully accepted by the millowners' body. I have told Mr. Trevors Edwards, who is the solicitor to the West Riding Rivers Board, that the moment he abandons the position which he is taking up, his Board are taking up, of abolishing sludging altogether, which would mean abolishing the water power altogether, and says:—"Now, how can we put our heads together; how can we best sludge out the dams; can we say that a year is too seldom; do it once in six months, or something of that sort." We should immediately become responsive. We should welcome anything of that kind, granted that dam sludging, which is the only practicable means of getting rid of this detritus, which comes to us down the river in the natural way is admitted. Granted that is admitted, that we have a right to get rid of it in the old, ancient way, with no harm to anybody, never having created an epidemic, or even a single case of illness, so far as we can find out, we are willing to have such regulations as may be reasonable, that would cause the least inconvenience to millowners on the stream and everybody concerned.

20116. Then the fact that your Association have agreed to submit themselves to these regulations, that you yourselves have drawn up, I think may be taken as proof by this Commission that in the absence of some control, self-control in this case, but in the absence of some control dam sludging may be a serious evil?—It may be an inconvenience.

20117. Well, put it that it may be an inconvenience?—You see, Mr. Chairman, may I differentiate between pollution and the other thing that we have got to avoid—that does not so much concern you, although it very much concerns us—the interference with the flow of the stream. These regulations are aimed to prevent just this. Two or three people might sludge their dams together at a time of dead low water; that material might go down the stream, and by reason of the stream not flowing at any rapid rate it would be precipitated, creating sand-banks—that was tried to be alleged against us—and so forth in the stream. Well, our object is to avoid all that, and also to avoid that we are sludging our dam, getting rid of our solid matter and sending it down the river in a state of suspension just as the river does when it is in flood to our neighbours' detriment, and to ensure that the other people down below should close their shuttles so that they should not have any portion of it coming into their dam, as they would have to repeat the process at a later date.

20118. In short, for dam-sludging some control is necessary?—I think it is desirable in the interests of everybody concerned in the river; but in the interests of the prevention of pollution I do not think any control is necessary, because I do not think, in a properly regulated stream, there would be pollution worth speaking about in the sludging of the mill dam.

20119. And we are to gather, are we, that if some reasonable control is in the hands of such bodies as Rivers Boards, you think that the manufacturers would willingly submit to reasonable conditions?—If, with all respect to the Rivers Board, I might suggest that there was an appeal to some body. I am not myself filled with admiration as to the moderation of the West Riding Rivers Board. On the contrary, I regard the West Riding Rivers Board, under its present policy, of being a body—I must say nothing offensive—of a distinctly interfering kind.

20120. Naturally; it is the nature of their business?—For my part, I think the West Riding Rivers Board would pursue their ideal to the extent of enabling boys to catch trout in the confines of the City of Sheffield, and would not care a little bit if by doing so they had to interfere, as they would interfere gravely, with the trade of Sheffield, and put an additional shackle on people already shackled badly enough in their struggle for life in trade in competition with other places.

20121. I am afraid the policy of the Rivers Board is not before us to-day. They cannot carry it out of necessity unless they interfere with somebody?—Mr. Chairman, you asked me if I would leave it to the Rivers Board. No, I would not. I think we need not go into that subject, but some body, probably the Local Government Board, should have a voice in the matter, or on appeal, as to any regulations. Then, by all means, if it is thought that regulations, further than those we have made, should be adopted, let them be put forward.

20122. Are you familiar with the Third Report of this Commission, in which a suggestion was made that in connection with trade effluents, for instance, there should be in the first instance an appeal to the Rivers Board, and from the Rivers Board to a Central Authority in London?—Yes.

20123. Then such an appeal would meet your difficulty?—It would meet the difficulty of regulation only. Mind you, I do not give way on the question of regulations unless it is admitted that the dam sludging is to go on. I mean to say the dam sludging, subject to regulations, yes; regulations which would abolish dam sludging, no.

20124. You mean that under no circumstances would your Association desire to consent to removing the sludge in carts or barges on to land; is that what you mean?—All I have to say about that—I am glad you have mentioned that now—is this: It is as absolutely impracticable as anything could possibly be. Take the City of Sheffield, now; take the works in the City of Sheffield which have refuse to get rid of, furnace slag and so forth. What happens to it? Well, it has to be carted, perhaps, from two and a half to three miles from the works. When it gets to its destination it has to be deposited at a cost of from 6d. to 9d., and in some cases 1s. per cubic yard. Practically speaking, it would be absolutely prohibitive; you would not be able to use your water-power if you had to remove the proceeds of this; which, of course, in this instance is really the natural detritus coming down the stream. The weight of material which requires to be moved would be immense, not harmful material, but the ordinary sand and detritus that comes down the stream.

20125. But you say it would be impossible—I suppose financially impossible—for a manufacturer to remove the sludge from his mill dam, but, as a fact, does

not almost every manufacturer have to cart away his ashes from his boilers?—Yes.

20126. And trade detritus of a solid kind?—Yes; but the power you get from the dam is somewhere about 40-horsepower, we will say; there is horsepower that does not cost you anything. If you remove the detritus brought down by the alluvial stream to the land from your dam you will be removing a very large amount of material as compared with the 40-horsepower, as compared with the ashes and slag and so forth from a 40-horsepower engine.

20127. Do you suppose it would be more?—Undoubtedly it would be more.

20128. Why, it would only have to be moved probably once in a year or once in two years?—I honestly wish that the Commission could not just have to hear what I have to say, but would come and have a look at a mill dam when it is sludging out and see the masses of sand and material that have to go down the stream just as it is brought by the stream. I assure you it is a very difficult problem, and it was attempted in evidence in our case to be proved by the West Riding Rivers Board, by way of showing that what they were doing was not unreasonable, that we could remove this material, and that it would cost us very little to do this, while the fact was just the opposite.

20129. As a fact, in many cases it is so, is it not; possibly not in your district, but in others?—As to that, unless I absolutely know the circumstances, I should not like to pass an opinion. What I do know is this, that the waters of the River Don give us free power to the extent, perhaps, in some instances, of 40-horsepower free. I say that if upon the advantage of that you put the difference between sending men into the dam to loosen the stuff, and letting the river, as it will, carry it down, and the carting of the material from the dam to carts to take it away from the place a long distance, and the money you have to pay to deposit it, I simply say that it would kill the water power, that is all. And what I ask the Commission is this: As I said before, I am, and so are these millowners that I act for, absolutely in favour of stopping anything which puts human life in peril or brings sickness, but what we ask you, and any body of gentlemen who are addressing themselves to the subject, is this: If it cannot be proved that the sludging of the dam produces illness, sickness, or some other thing which is not consistent with trade, why should you interfere with trade to the extent of abolishing dam sludging which does no harm? Now, let me put to you why I say my people are in earnest in that. You are, I dare say, aware that we are largely dependent for water power on the supplies of water—called "compensation water," which is provided by Statute; public bodies impound the water as Dewsbury, Barnsley, and Sheffield have done—Sheffield's "compensation" from the Loxby and Nevelin watersheds being as much as 9¼ million gallons a day, we are dependent upon that water, but never once have the millowners refused to give up that supply in times when they wanted it most—for a consideration, of course, but to give it up when it was worth a great deal more to them than anything they got for it, because of the domestic needs of the people. Now, on that we have always given way, and always recognised the domestic needs of the people for water.

20130. I do not think it is a matter so much of sickness, as of inconvenience. For instance, the manufacturer below on the stream, your regulations imply that there is inconvenience of that kind unless proper precautions are taken?—Yes; inasmuch as the detritus goes into other dams.

20131. Your evidence is largely limited to a stream which is almost unpolluted, and I do not know that I need keep you longer by asking you any more questions?—I should just like to say one thing, and that is this: There are a great many dams; as you will see, they are printed here; here is a list of the works which are on the Don; you will see the number of people who are using this water-power over and over and over again. You can imagine how valuable it is when you look at the list of names. Well, now, dam sludging has gone on up to the present time. I have never heard, in the whole of my twenty-eight years' experience in Sheffield, any complaints whatever on the part of the people who were taking in the waters of the Don for engine purposes in Sheffield, of which there are a large number, of any inconvenience whatever caused by solid matter in suspension, arising from the sludging of dams.

20132. But surely that is due to the regulations under which your association works?—Precisely; and, as I told you, I would not object to regulations of that type.

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20132A. Before asking my colleagues if they have any questions they would like to ask you, I may mention incidentally this: I know a little of the subject before us, that the waters of the Don were generally acid, and that the alkalis used in connection with sewage treatment had their utility. That acidity is largely due, is it not, to the sending into the stream of water from mines?—Well, the ochre water has some effect.

20133. Is it not mainly due to the ochre water, or is it to the pickle?—I should rather be inclined to think that it was material from the wire mills—which had a good deal more to do with it, the acids from there. You will remember some time ago there was a great scare about lead-poisoning. It is a peculiarity of water undeniably pure which comes off the moors in our neighbourhood that it does contain a quantity of acid, and that the acid will take up the lead from lead pipes, and therefore also attack other metal, and that that has to be neutralised, as it is neutralised by the adding of chalk, and so forth; so that practically you have got a state of things arising with the pure water which is drunk by the people of Sheffield, and which is as near purity as you can possibly get, because it is nothing but water running off moorland into the reservoirs. That water carries acid with it, and if it is not neutralised by chalk it will take up the lead of the pipe and produce lead-poisoning.

20134. So that you have three sources of acid?—Yes.

20135. The natural source of the moorland waters?—Yes.

20136. And the ochre water and the effluent from the wire?—Yes. I thought you had heard of it, because it led to a scientific discussion. Many causes were alleged as to why the water was acid and why it took up lead.

20137. *(Mr. Stafford.)* Have you had any analyses made of this sludge?—Oh, yes; very careful analyses have been made with the view of proving that it is polluted, and those analyses were put in proof in our case. Analyses by the whole of the staff of the Rivers Board and the County Council were taken most carefully. They had bottled the effluent as it went down while the sludging was going on, and brought that evidence before the Courts.

20138. What was the result of these analyses?—It did not prove pollution. It was all right from appearance point of view. They shook up the bottle, and it went rather black-looking, and that was supposed to create an effect, but the analysis utterly failed to show that it was polluted.

20139. Do you hand in any of these analyses in your statement?—No, but I should think you could get at them. The proceedings in the case would be open to you. I should be very pleased, indeed, if the Commissioners would like it, to send them the shorthand notes. I have only one copy—they could easily have them printed if they wanted to—of the trial before the Quarter Sessions which raised the facts, and you will see the facts.

20140. It might be interesting to have the analyses ———*(Chairman.)* We could get these from the Rivers Board?—It does not matter whether you get it from the Rivers Board or myself. We had a joint shorthand note.

20141. You tell me the pollution was not proved?—Oh, no; if it had been ——

20142 Do you assume that is so because the prosecution failed?—That is the only ground upon which it could fail.

20142*. Was there not another ground—that there is an exemption, is there not, in connection with the Rivers Pollution Act, if you merely send down what belongs naturally to the stream?—One moment, Mr. Chairman. You may send down the natural detritus, but listen to this proviso—this is what we were attacked upon:—"Provided that the sand or gravel or other natural deposit so put back or carried as aforesaid does not interfere with the due flow of or pollute the water of such river or stream." So that if they could have proved pollution—it was what they tried to prove

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—or if they could have proved interference with the due flow, which they also tried to prove, we should have failed; but, as a matter of fact, they tried to prove them both, and failed to prove either; therefore we got our case.

20143. *(Mr. Power.)* Apart from obstruction or pollution, was there any evidence produced that people had suffered disadvantage from the sludging?—No; that disadvantage is legitimised by the Act if there be a non-polluting discharge.

20144. I mean riparian people?—No, I have never heard. No; there was no case made of that sort. so far as I know.

20145. Is there another river Don in the West Riding which is connected in any way with Heckmondwike?—Not in the West Riding, so far as my knowledge goes. There is the Little Don, which is a tributary to the Great Don; that is the river on which Sheffield has made its new waterworks.

20146. The Don flows, after leaving Sheffield, through Rotherham and Doncaster?—Yes, and down into the Trent, and from the Trent into the Humber.

20147. Oh, that way?—I think so. I will not be absolutely certain, but if you had asked me some time ago I should have been familiar with it, because we had a case in which the point occurred. The Don runs into the Trent, and the Trent runs into the Humber. I think that is the course of the river.

Statement handed in by Mr. Herbert Hughes, C.M.G., Clerk to the Don Millowners' Association.

RIVERS DON, LOWER DON, AND LOXLEY MILLOWNERS.

Rules as to Sludging out Dams, adopted at a General Meeting of the above-named Millowners, held at the Cutlers' Hall, Sheffield, on Tuesday, the 28th day of June, 1898:—

1—All Dams upon the stream should be cleaned out every year.

2.—The time for sludging out Dams should, if possible, be during holidays or general stoppages, but no Dam should be sludged unless there is a good flow of water in the main stream.

3.—As much water as possible should be passed through the Dam at the time of sludging, so as to carry it away rapidly and in as fine particles as possible, and the work, when once commenced, should be carried out expeditiously.

4.—Information must be conveyed 48 hours before sludging a Dam to all the Millowners down the stream within a distance of five miles, and to the Manager of the River Don Navigation Corn Exchange Buildings, Sheffield.

5.—In case these Rules are not generally adhered to by any Millowner, he shall not be entitled to be defended out of the funds of the Millowners in case a Summons is issued against him for sludging his Dam.

Dated this 5th day of July, 1898.

Herbert Hughes, Clerk to the Millowners.

LIST OF MILLS AND WORKS ON THE RIVERS DON, LITTLE DON, AND LOXLEY, TOGETHER WITH THE NAMES OF OCCUPIERS.

RIVER DON.	RIVER DON—*continued.*	RIVER LOXLEY.
Bullhouse Mill, Penistone. Goldthorpe and Hinchliff.	Beeley Wood Steel and Iron Works, Wadsley. Henry Burkinshaw.	Bradfield Corn Mill, Bradfield. J. Crapper.
Millhouse Works, Penistone. W. Smith.	Clay Wheel, Wadsley. Thos. Firth and Sons, Ltd.	Storrs Bridge Forge, Loxley. Swift Bros.
Eckland Bridge Works, Penistone. W. Hoyland and Co.	Niagara Forges, Wadsley. A. Stringer.	Old Wheel Steel Works, Loxley. Thos. Wragg and Sons.
Plumpton Mill, Thurlstone. Thos. Tomasson and Sons.	Marshall's Forges, Wadsley.	Ashton Carr Mill, Loxley. C. V. Bunting.
Thurlstone Corn Mill, Thurlstone. F. Booth and Son.	Wardsend Steel Works, Wardsend. Wardsend Steel, Company.	Rowell Bridge Wheel, Loxley. Pitchford and Elliott. W. Williams.
Thurlstone Oil Mill, Thurlstone. W. Whiteley.	Old Rolling Mill, Owlerton.	Olive Paper Mill, Loxley. B. Swift.
Nether Mill, Penistone. Goldthorpe and Hinchcliff.	Old Park Corn Mill, Owlerton.	Little Matlock Works, Loxley. Kenyon Bros. and Co., Ltd.
Oxspring Wire Mill, Penistone. G. Winterbottom.	Old Park Silver Mill, Neepsend. Old Park Silver Mills Co., Ltd.	Green Wheel Tilt, Loxley. C. V. Bunting.
Oxspring Corn Mill, Penistone. Thomas Dransfield.	Clifton Steel Works, Neepsend. Jno. Hy. Andrew and Co., Ltd.	Glass Tilt, Loxley. Pattinson and Co.
Old Wire Mills, Thurgoland. Jagger Brothers.	Philadelphia Steel Works, Penistone Road. Burys and Co., Ltd.	Loxley Steel Works, Loxley. H. Denton.
New Wire Mills, Thurgoland. G. Wordsworth and Sons.	Britannia Corn Mills, Alma Street. H. & W. Ibbotson.	Wisewood Forge, Loxley. J. Wood and Sons.
The Tilt Mills, Thurgoland. Joseph Dyson and Co.	Millsands Works, Millsands. Sheffield Forge and Rolling Mills Co., Ltd.	Wisewood Rolling Mill, Loxley. J. Wood and Sons.
Upper Forge, Low Forge, and Tin Mill. Thomas Andrew, Wortley Iron Forges.	Wicker Tilt and Forge, Wicker.	Malin Bridge Wheel, Malin Bridge. German Wilson.
Deepcar Mills, Deepcar. John Armitage and Sons.	Wicker Wire Works, Blonk Street. J. G. Cocker.	La Plata Works, Malin Bridge. Burgon and Ball.
Dyson Holmes Forge, Oughtibridge. Josh. Rodgers & Sons, Ltd., Norfolk Street.	Don Steel Works, Savile Street. Francis Hobson, Seaman, & Co.	Limerick Wheel, Malin Bridge. Ward and Payne.
Spring Grove Corn Mill, Oughtibridge.	Royds Mill, Attercliffe. Thos. Marrian and Co., Ltd. Edwin Whitton.	Owlerton Wheel and Wire Mills. Woodsworth and Sons.
Spring Grove Paper Mills, Oughtibridge. P. Dixon and Sons.	Attercliffe Steel Works, Newhall Road. Sanderson Bros. & Co., Ltd.	Nether Owlerton Wheel, Owlerton. S. Laycock and Sons, Ltd.
Oughtibridge Forge, Oughtibridge. A. Blackwell.	Brightside Works, Brightside. W. Jessop and Sons, Ltd.	Owlerton Old Paper Mill. S. Laycock and Sons, Ltd.
Oughtibridge Low Tilt and Corn Mill.	**LITTLE DON.**	Birley Meadow Tilt, Owlerton Denton and Best.
Middlewood Iron and Steel Works, Middlewood. S. A. Parkin.	Midhope Corn Mill. Herbert Woodhouse.	Upper Slack Works, Owlerton. D. Doncaster and Sons.
Middlewood Forge and Rolling Mills, Middlewood. George Clarke.	Stocksbridge Works. Saml. Fox and Co., Ltd.	Nether Slack Works, Owlerton. Thompson Bros.
	Henholme Pipe Works, Deepcar. J. Armitage and Sons.	
	Deepcar Mill.	

J. Selwyn Rawson called in; and Examined.

Mr. J. Selwyn Rawson.

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20148. *(Chairman.)* You are a millowner?—Yes.

20149. On the river Don?—The river Ryburn.

20150. Which flows into the Don?—No; it flows into the Calder; it has no connection with the Don.

20151. Where is your mill?—It is upon the stream above Sowerby Bridge.

20152. You have no connection with the Don?—No; it is a different district altogether. It really starts on the Pennine Range, higher up on the Blackstone Edge Range.

20153. Then the stream on which you are situated is the——?—The river Ryburn.

20154. And that is a tributary of the Calder?—That is a tributary of the Calder.

20155. Then is that stream, as it comes to your mill, substantially a pure stream, or are there dams above you?—There are dams both above and below.

20156. Is there any sewage coming into the stream above you or any trade pollution?—There is very little trade pollution, but in the evidence that was given in our case when we were prosecuted by the Rivers Board it was stated that there were 490 cottages which drained into the river.

20157. Above you?—Above us. I am not here to dispute that; my own evidence was that there were 120.

20158. It is immaterial?—It took a larger range.

20159. You agree there is sewage coming into the stream?—Yes.

20160. And therefore by impounding the waters at your mill you are holding up something of the sewage or suspended matter which otherwise would pass down into the stream?—Yes, we are holding up a certain quantity; we must do.

20161. Now, do you suggest by doing that you do not cause any evil to arise, first of all in your dam and afterwards in the river in times of sludging?—No; I do not think so.

20162. You absolutely hold, do you, that no evil is produced?—Yes; we never have had any complaints. From the mills above we have never found anything to complain about, provided they did, as it seems the Don millowners do, sludge at holiday times and give the lower millowners notice.

20163. *(Mr. Power.)* What is the next nearest to your mill, of the mills below you?—Major Morris's.

20164. How far?—If I might explain; the mill that we were prosecuted for is not my mill now. My brother and I were running it, and we have since given up manufacturing, and it is not used now. That was the Thorpe mill dam, the next mill dam below us was Morris' dam, which is about a quarter of a mile below; then, again, after that I have a mill dam which is about 200 yards below that, and then about another quarter of a mile below my cousin has another mill dam, so we are all on the same stream.

20165 The dam of your disused mill will now be shut off from the river, or will that continue to be sludging up?—No, it is disused for anything except running a dynamo.

20166. *(Chairman.)* If you had a mill dam immediately below you, you would think it necesary to give them notice when you were to sludge?—We always did; as a matter of courtesy we used to two miles further down the river, as far as Sowerby Bridge.

20167. Then a temporary evil does arise, and you think it necessary to warn persons down a stream to close their valves?—The evil would arise from the fact that below our mill dam, at the next mill they have a mill weir, and if we did not sludge in a holiday time, or if there is very little water going down the river, all our sludge, or, at any rate, a considerable portion of it, being so close together, would pass into their dam.

20168. So it is necessary to have some control?—I think so.

20169. You agree that some control is necessary?—Oh, I do not dispute that at all.

20170. Are we really to take it as your deliberate opinion that the upholding of these matters, partly sewage matters, in the mill dam, produces a sludge which is innocuous, which is likely to give rise to no nuisance at all, even if let out at long intervals and large quantities?—If I might go back——

20171. We will take that from you if it is your view?—Oh, yes, it is so. I was only going to say, if I might go back 30 years, we used in those days to sludge our dams, as a rule, once every three or four years; not every year, and the river was full of fish; we never found that it damaged the fish in any way; to-day there is no fish in the river.

20172. *(Mr. Power.)* Were the dams sludged, many of them simultaneously?—No; I do not think so.

20173. Or in regular order?—No; I do not think so, because we should, perhaps sludge once in three years, and we usually did it at holiday times.

20174. What is the effect of giving notice; is it not that perhaps all mills sludge their dams at once and the same time?—Oh, no, not at all.

20175. *(Chairman.)* Then, though you have not had any complaints, you say, in regard to the sludging of the dams, which you no doubt carry out so as to avoid as far as possible producing any evil, you know that on other streams there have been serious complaints of dam sludging, do you not?—Well, I could not say anything about that. I do not know that any millowners have ever complained to us, and I never heard of any doing so on our stream.

20176. But you recognise that it will, temporarily at least, largely increase the suspended matter in the stream if you sludge out a dam which has not been cleaned for a year or so?—It will for a mill possibly down the stream.

20177. And you recognise the necessity of some control of dam sludging?—I do not think there would be any harm in it, supposing there was reasonable control.

20178. As a fact, nobody has any control of dam sludging at present?—No; they have not.

20179. And you think it would be reasonable that somebody should be given such control?—I think so.

20180. Would you be satisfied to place it in the hands of the Rivers Board, subject to appeal to a Central Authority?—Yes, I think so; subject to appeal. The Rivers Board, I know, are a very hardhearted body.

20181. *(Mr. Power.)* Have you at present on your stream any general rules governing sludging?—No; none whatever. We have no Millowners' Association on our stream.

20182. *(Chairman.)* At present there is no control?—No; none whatever.

20183. You think that control is reasonable?—Yes; we have never had any case of complaint from our neighbours.

20184. If damming sludge were prohibited, and you were compelled to remove your sludge in carts or barrels on the land, would you consider that would be a prohibitive expense for a manufacturer?—Well, in two instances. In one instance, the mill dam above the Thorpe dam, it will be an impossibility almost.

20185. In certain cases?—Yes.

20186. But in many cases it would be possible?—My own dam it would be almost impossible to remove it, because on the one side there is a precipitous rock you could not get up or down; in fact, it is cut out of the side of the hill almost, and on the other side there is a bank which is too narrow to get a cart and horse up between the stream and the mill dam. The dam is a matter of 200 to 300 yards long and 60 yards wide.

20187. Then, in such case where, owing to the local situation, it would be very costly to cart away the material, you would suggest that it would be better to let off the dam much more frequently?—Well, we do let it off as frequently as possible on Saturday afternoons.

20188. That is the remedy you suggest, is it not?—Oh, certainly.

20189. *(Mr. Power.)* Have you not an alternative—namely, dredging from a flat-bottomed boat and conveying off the material to one end of the pond and there loading it into a cart and carrying it away. That might be possible under such circumstances as your mill dam?—It would be an enormous expense, I am afraid.

20190. Do you think it would?—I think it would.

20191. It is done, you know, constantly in navigable rivers?—I know it is in rivers.

20192. In rivers and mill dams in some parts of the South of England it is very frequently done. It is done pretty frequently, not waiting five or six years. It has the advantage that it does not send large masses of suspended matter down; it takes a great deal of it out?—I have never seen it done except dredging in harbours.

20193. I do not know the relative cost of dredging compared with that of running sludge away?—Suppose we had to take and wheel this out. Of necessity before you could wheel it the mill dam would probably have to be emptied, and remain empty for a week or ten days, because it is quite thin, and it would require to stiffen before it could be dug or wheeled, so that it would, in the first place, mean closing the works for a week or ten days, and then I should say it would probably take nearly a fortnight to empty any of these mill dams by wheeling out.

20194. The dredging plan from a punt would be preferable in that it would not stop the works?—If it could be done, certainly.

20195. If it could be done?—In this Thorpe mill dam, at the end where it discharges into the river, the lower end, it is about 15 feet below the bank, so that would all have to be either lifted by a steam crane or else wheeled up from steep planks.

20196. (*Chairman.*) There are many cases where it is quite possible to do this, are there not?—To wheel it out?

20197. Yes?—Oh, there are, certainly.

20198. Where there is adjacent land?—Yes, certainly; if it were possible to wheel it out at a reasonable cost I would wheel it out myself.

20199. You think that would be a proper thing to insist upon where practicable?—Except for the expense; as I say, having to close the works down for two or three weeks.

20200. (*Mr. Power.*) It has some value as manure, has it not?—Certainly; I should be very glad to get the whole of it out for my own land, very glad indeed, if it could be done at anything like reasonable cost.

20201. (*Chairman.*) Would it not be possible to pump the sludge?—Oh, no, it would be too stiff.

20202. Instead of leaving it empty for a fortnight in order to dry this material and then another fortnight empty while you cart it away, would it not be possible to pump the sludge out without emptying the dam?—No; it would be too stiff; you could not pump it.

20203. Would you give us your opinion upon another suggestion which has been made to us, that it is possible to construct the bottom of the dam inclining to a well, and to let pass away from the bottom of the well under pressure of the water in the dam certain quantities of sludge at frequent intervals?—Oh! the sludge would never reach the well. Take Thorpe Mill, with which I am best acquainted, as I have lived there 30 years, in that case, at perhaps 60 yards from the top, there is nothing but sand, pure river sand; in fact, we have wheeled out thousands of tons. We used to wheel out hundreds of tons a year. There was a very ready sale for it, and after a flood a large quantity was always brought down of pure river sand, and we used to draw the dam off on Saturday afternoon and holiday times and put a lot of men in and wheel it on to the bank, and we had a very ready sale for it at 1s. 6d. to 2s. a cart-load. Men would fetch it at that for building purposes.

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20204. It would seem, then, that this carting away in that particular case was very practicable?—That was at that end; that was about 60 yards from the top. Then you came down, further down to the sludge, and when you got to about 60 yards from the entrance from the stream it tails off into ashes and anything of that sort, and then into fine sludge, and, of course, as you get lower down the mill dam was considerably wider and considerably deeper; it was only at the top end where the sand settled.

20205. Then, in impounding these waters you do so, of course, for the advantage that arises from that to you?—Oh! yes, certainly.

20206. That advantage is of considerable value, is it not?—Yes, it is.

20207. And it seems fair enough, does it not, to attach certain responsibilities?—On the one hand we get the benefit; we get the pull, as we say, over the people down nearer Halifax by having water-power, but, on the other hand, we are so far out into the country that the cartage of coals for the engines and the cartage of goods, and general expenses come to more, so that if it were not for that we should be at a great disadvantage.

20208. Well, briefly, your view, then, is that in your district the sludging of your dams has not given rise to serious complaints, that you think some control of dam-sludging is reasonable, that you would be ready to entrust that control to the Rivers Board with an appeal to a Central Authority, and that in those cases where it is not practicable to remove by carting, the best thing to be done is to frequently empty the sludge?—Yes. I may say that the millowners, as a rule, do usually draw their dams—I do not say sludge in the usual meaning of the word sludge when I am speaking of sludging, but—draw their dams off at holiday times and when there is plenty of water, and then turn on 30 or 40 men with spades or rakes and rake it into the stream as it passes through.

20209. That is just what is complained of, of course?—Well, what a good many of the millowners do is this: Whenever there is a fresh on a Saturday afternoon, when they can allow the mill dams to be drawn off, they open their shuttles and let the whole of the water through, because naturally the more water we can collect in the mill dams the greater horse power we get, so it is beneficial to keep the dams as clean as possible. We do that for our own benefit. But still the water then in those cases makes one or two defined channels through the mill dam, and the sludge, which, of course, has been in suspension, settles over the whole of the dam, so it does little more than wash out these defined channels.

20210. The rest is pulled in?—The rest is pulled in at the sludging time. I should like to say, as I said before, that there used to be a large number of fish in the stream, and there would be to-day, I believe, were it not for the fact that there are paper works. It is the paper works that have caused the fish to be done away with altogether. There are some paper works started up above us. Of course, that is another matter.

MR. A. F. SOMERVILLE called in; and Examined.

20211. (*Chairman.*) You are the chairman of the Sanitary Committee of the Somerset County Council, and have been so for some years?—Yes, since 1894.

20212. And you have some personal experience in the neighbourhood of your own home, I believe, of the evils caused by dam-sludging?—Yes; unfortunately I have.

20213. Would you tell us: you have, I think, in the stream above you several of these dams, have you not? But, first of all, you are on the Doulting stream?—Yes.

20214. And that is three miles from Shepton Mallet?—The Doulting stream, the Ordnance Survey people called the Sheppey the other day, which they had no reason to. The real old name of it is the Doulting Water, the Doulting stream. It is marked in the map as the Sheppey—that is a new technical name. The source of the stream is one mile above Shepton Mallet.

20215. One mile above Shepton Mallet; it is quite a pure stream?—Yes; quite a pure stream.

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20216. The first dam is at Shepton Mallet?—Yes.

20217. The first dam is at Shepton Mallet?—The first one of any size is at Shepton Mallet, and I think that is the only one there which is used now, and one below Shepton Mallet, at Bowlish, which is a hamlet of Shepton Mallet, and then there are two in the village of Croscombe; so there are four altogether.

20218. And although the stream above Shepton Mallet is substantially a pure stream, there is considerable pollution from sewage in passing through the villages from Shepton Mallet downwards?—They have got a sewage farm at Darshill, the effluent of which goes into the stream, but the effluent is very much better now than it used to be.

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20219. But there is also some crude sewage from cottages?—There is a certain amount of crude sewage from houses in Shepton and Croscombe.

20220. We may take it there is some crude sewage and some sewage effluent, perfectly or imperfectly purified?—Another sewage pollution, very serious pollution, is the large amount of droppings on roads. That road between Shepton and Dinder, where I live, is a road which is largely used for driving cattle to market, and there is a good deal of horse traffic on it too.

20221. In times of rain?—In times of rain all this is carried down into the stream.

20222. Tell us what you find from your experience to be the effect of the holding up of the waters of the stream and the accumulation in the dams of the suspended matter coming down?—So long as the hatches are down, of course, the suspended matter is precipitated—we get the water fairly pure.

20223. No nuisance arises from the dams themselves except at the times of sludging?—No, oh! no; it is rather the other way, you see.

20224. They help to keep back matters brought down by the stream?—Yes.

20225. They are really precipitation tanks?—They are precipitation tanks, and the stream being pretty rapid below, the amount of pollution which arises in these dams from the deposit of sludge is removed by the passing of the water in a rapid way down the stream.

20226. Then if these dams were emptied so as to bring about the removal of their sludge on to land there would be a positive benefit to the neighbourhood?—Oh! yes; certainly.

20227. But as a fact that is not done scarcely?—No.

20228. And the sludge is pushed into the stream at long intervals?—Yes, that is what I complain of. I have been listening to the replies of the two last witnesses, and I was very much amused at one remark the last witness made. While I think of it I should like to refer to it. He said there was no pollution in the deposited matter in the dam, and yet at the same time he considered it was very valuable matter to put over his land. Now the two things do not agree. If there is no pollution, if the matter is not a polluting substance, it is absolutely useless when you take it as a manure, and the fact that it has a manurial value and contains ammonias which make it, of course, of value to put into the land, proves that the sludge is a polluting substance.

20229. If there is organic matter present?—Yes.

20230. Then what kind of nuisance has arisen from the sludging of the dams in your district?—Chiefly this, that the times when they sludge are the holiday times. The holiday times are the driest times of the year, when the river is at its lowest, and the result is that of late years they take advantage of these holiday times to draw up the hatches. They send men in—a full army of men—with shovels and scrapers, and they scrape the whole of the stuff down into a very diminished stream, and it comes down solid mud. But when that happens there is, first of all, the blocking of our ponds and the stream below, and, what is a far more serious matter, is that it is absolutely impossible for the villagers below to use the water while this is going on; and, moreover, the cattle in the summer are all turned out in the fields—in the winter some of them would be in the houses, but in the summer they are in the fields—and they cannot drink the water. I have known cases where cattle have gone down to the water and have actually turned back and have been sick after drinking this foul water; others will look at the water and turn away without attempting to drink it.

20231. It is visible?—You can feel it; it is like Egyptian darkness.

20232. *(Mr. Power.)* Does it smell at all?—Smells most foully. This matter which is deposited in the mill dam is a putrefying matter; it is organic, and it goes on putrefying, consequently. The top layers, as Mr. Rawson said, are sometimes valuable river sand, but, when you get down into the horrid polluting, organic matter, and this is put down the stream, it comes down with a low head of water in a most polluted state, and stinks like a sewer.

20233. It replaces the river water for the time being?—It fills this little stream of river water with a highly polluting substance.

20234. There is a large bulk of it in comparison with the water in the stream?—Yes.

20235. *(Chairman.)* That is last year?—Last year was the worst year we have had; it lasted nearly two months.

20236. How was that?—They did it for a week or a fortnight—I think at the mill they were carrying out some repairs—and then after that they did it on Saturday afternoons. The mill stopped off on Saturday, and men went into the dam every Saturday during the summer days; they would work, say, from one or from two up till six.

20237. *(Mr. Power.)* The same dam, do you mean?—The same dam. It had not been sludged out for a long time. I never saw it so clean as it was. It required two months. It takes a long time to get the mud out, unless you do it systematically. The last time I saw it cleaned out systematically I remember as distinctly as possible that it was done with horses and carts. Of course, it is most expensive. Where I could get mud thrown at 3d. a load I paid the other day 5d. I know it is more expensive. I look upon it as part of the working expenses of the mill.

20238. *(Chairman.)* Have you not any remedy at common law?—Yes; you have a remedy, but the difficulty is this: when one mill dam is sludging, the millers below start to sludge, too, or else it would fill up their dams; but while the unfortunate people lower down get the damage done, they cannot identify the actual amount of sludge which is coming down as belonging, we will say, to mill "A"; it belong to "A," "B," and "C."

20239. The remedy at common law is the bringing home to any particular mill the source of the pollution?—You must fix upon one man, and I do not think that a joint action would lie against all three.

20240. Now tell us, do you think the case would be met if some control in regard to dam-sludging were placed in the hands of either Rivers Boards or other authorities that might be arranged?—Yes; if the Government would kindly constitute Rivers Boards, or would compel County Councils to have medical officers of health, I think that something might be done.

20241. Do you think that a Rivers Authority dealing with the watershed would be very valuable all over the country?—Well, I think it would; but, still, I do not see why it is necessary to multiply authorities.

20242. You think the powers could be excercise by the County Council?—I think our Sanitary Committee could deal with the matter if we had a medical officer of health and a proper staff to deal with it, and I do not think that would be any more expensive than constituting a new authority.

20243. Would control, whether placed in the hands of a Rivers Authority or the County Council, of the sludging be sufficient without absolutely prohibiting the passage of the sludge into the stream?—I think that there ought to be prohibition of this scouring, certainly. By scouring I mean to say the sending men to scrape down the sludge.

20244. What I mean is this: If, for instance, the period of flood were selected for the dam sludging, first of all, is it practicable to select such a period, and then would the passage of the sludge at the time when the river was swollen do much harm?—I do not think it would do nearly so much harm. It would be quite a different thing if sludging were simply by pulling up the hatches, as I understand from the last two witnesses is usually done in their districts, and men were not sent into the dam to scrape it down, and if those hatches were simply pulled up, and there was no sludging except during the time of flood in the winter. It should be prohibited altogether in the summer; that is the time we feel it most.

20245. Then the selection of the time for sludging would be one of the elements of control?—Yes.

20246. And the other would be the frequency of the sludging?—Yes.

20247. *(Mr. Power.)* Would it be a grievous burden to put on some millowners, for instance, the obligation to dig out a dam? A few years ago, you say, it was the custom to do that, and now they have given it up; why is that?—Oh! it is simply to save expense, because the law allows them. If the law allows a man to do a

thing which saves him expense he certainly will not go to further expense for the sake of his neighbours.

20248. (*Chairman.*) You think that under the Rivers Pollution Act they have the right not only to impound the water, but to send down the stream the matter which has been brought down the stream?—I think it was an unfortunate construction put on the Act by the Courts above. I do not think it was intended.

20249. Do you think there should be an alteration of the law to meet this case?—Yes.

20250. You really think the case is a serious case?—Oh! yes, a very serious case. These two last witnesses looked upon the rivers as the property of different mill-owners, A, B, C, and D. I look upon them in quite a different light, as public property, in which are interested riparian owners, villagers, and owners of land generally.

20251. Do you wish to make to this Commission any suggestion except those which have been brought out in your answers?—No; I think not, except this: that I am inclined to discriminate between streams in purely country districts and rivers such as are mentioned above, which are always of a polluted character. There is no reason at all why our streams should not be sufficiently good for nearly every purpose. Our own stream would be with a little asistance from the County Council. If we had a medical officer of health and that sort of thing, I think we could make most of our streams pure. But in that case I think the sludging ought to be stopped. I would go so far as this: I would allow the hatches to be drawn at a certain time of the year, but I would not allow any sending of men into the dams and scouring them down—raking down the sludge. When the mill dam required to be emptied, then I think the hatches might be drawn, and the sludge dug out and carted away. I think there would be no harm done in that, and if there was any special case where the sludge could not be dug out and carted away, then I think special leave ought to be given.

20252. There is just one other point I would like to ask you, and that is: There are a certain number of streams with what one might call derelict weirs, are there not?—Yes. *Mr. A. F. Somerville.* 8 Dec. 1904.

20253. Do you think that some power should be given to some authority either Rivers Authority or County Council, to deal with derelict weirs?—Certainly. I think that is most important. I think that there should be power given to Rivers Boards or some authority like that to remove them. I think that is a very important matter, because there is no doubt about it that the freer the stream is from weirs the more purification takes place.

20254. (*Mr. Stafford.*) It is only during the sludging, I understand, that the nuisance arises?—I will not say that. I say the serious danger arises at that time. We suffer a good deal at other times. Every Saturday night the miller draws his hatch, and a certain amount comes down, but the pollution is not at all of the same villainous character as it is when it is done by scouring out the pond.

20255. But the chief nuisance apparently arises at the time of the sludging, which is about once a year?—Yes, and generally when the water is so low: that is my point.

20256. Would not the cost of removing all this sludge by hand, or rather by carting, be very great?—Oh! no I did it myself last year. I removed a great deal from the ponds in front of my house, and I forget exactly what it cost, but it certainly paid for expenses for spreading on the land.

20257. It paid for its expenses?—Yes; of course. I know I spent £38, and I forget exactly how many yards I removed for that. That would clear a good many small mill dams.

20258. Thank you?—I am much obliged to you for allowing me to give this evidence before you.

20259. We are very pleased to have your views.

SEVENTY-FIRST DAY.

Friday, December 9th, 1904.

PRESENT:

Colonel T. W. Harding, J.P., D.L., in the chair. | Major-General Constantine Phipps Carey, C.B., R.E
Mr. W. H. Power, C.B., F.R.S. |

Mr. F. J. Willis, *Secretary.*

ALSO PRESENT:

Dr. A. C. Houston. | Dr. George McGowan.

Mr. R. A. Tatton, recalled; and further Examined.

20260. (*Chairman.*) Mr. Tatton, you are the Chief Inspector of the Mersey and Irwell Joint Committee?—I am.

20261. And on previous occasions you have given us valuable evidence; and to-day you have been good enough to come in order to give us the benefit of your experience in regard to the evils connected with the sludging of mill dams?—Yes.

20262. Now, we had certain evidence yesterday which tended to show, on the part of the persons holding or using the mill dams, that the evils of discharging accumulated suspended matters, which had been brought down by an unpolluted stream, were scarcely appreciable, and that it would be wrong to call upon owners of mill dams to go to great expense to prevent evils which they considered were unappreciable. Now, will you be good enough to give us your opinion in regard to mill dams in your district situated on unpolluted and polluted streams, and tell us whether you think that the evils are real evils, and then give us your opinion as to how those evils might be removed without prohibitive expense to the owners of the dams?—Would it be convenient, Sir, if I read my evidence in the first instance? *Mr. R. A. Tatton.* 9 Dec. 1904.

20263. Yes, you can read any part of it you like, Mr. Tatton, or give us briefly in your own words a summary?—I have divided the sludging cases which we have had in the Mersey and Irwell under two general heads, and we have in the first place the sludging of mill dams; and in the second place the sludging of tanks, precipitation tanks, which have been used by the manufacturers for precipitating their trade effluent. I take it that what you require is especially the sludging of mill dams.

20264. That, in the first instance, is the point upon which we want your opinion?—The waters of the rivers in Lancashire and Cheshire are very largely used for power purposes, and in order to obtain the head to work the turbine or water wheel, as the case may be, dams are constructed across the stream, and the water is either held up in the bed of the stream itself, or is conducted from these dams to a reservoir made, closely adjoining the river. In course of time, these mill dams get silted up by solid matter which is brought down in suspen-

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sion, and owing to the velocity of the stream being reduced, settles in the mill dams. This sludge contains organic matter, I may say, invariably, and is apt to be offensive in the summer; and mill dams, therefore, require cleaning out—at any rate they require the top water being let off—in addition to the necessity which arises of emptying the solid matter out, in order to retain their holding capacity of water. If the sludge is too solid to flow forward by opening the sluices it has been a common practice to send men in with scrapers and rakes and so on, to urge the solid matter forward into the stream. I should say the ordinary practice is first of all to open a sluice to draw off the top water and then to send men in with scrapers and so on to push the sludge forward into the bed of the stream, into the old bed of the stream, through which the stream is flowing when the sluice is opened: the stream then carries the sludge forward into the river down below. It causes very serious pollution, as, of course, the accumulation of probably, it may be, weeks or months or years, which has been settling in the sludge, is sent down in a very short time.

20265. Would you apply the expression very serious in connection with the evils produced from the settlement of matter from an unpolluted stream?—Of course, from an unpolluted stream it is so in a less degree.

20266. You think there is still material pollution?—Yes, there is material pollution. For instance, if it were a fishing river, it is sufficient to smother fish.

20267. Well, you would say it would smother fish. Have you had experience of fish having been smothered under such conditions?—Yes, I have. We had a case; it was not an absolutely unpolluted stream; perhaps I am wrong in saying that, but it was a case where the sluice was opened, and it was a fishing river below, and I had great complaints on two occasions about the fish having been smothered, killed by it.

20268. *(Mr. Power.)* It was detrimental to the fish through the suspended matter, I suppose; not through the sewage or noxious matter that had been in the water?—No.

20269. Would it smell at all on a pure stream?—Yes, it does distinctly; yes; but the fish are not poisoned; they are smothered; it is not from chemicals.

20270. *(Chairman.)* It is mechanical action on the gills, is it?—I suppose that is it, a clogging of the gills.

20271. *(Mr. Power.)* Do people below such a mill dam as that we are speaking of now on an unpolluted stream, complain of disadvantages which arise from sludging?—Yes.

20272. Apart from damage to fish, do they say it is a nuisance or an annoyance or a trouble to them?—Oh, yes, certainly they do. On all streams you get a considerable accummulation; if the water is held up, we will say, for years you get a lot of black mud settling on the banks.

20273. You get leaves and vegetable matter?—You get decaying vegetable matter.

20274. *(Chairman.)* In the case of dams and unpolluted streams what do you find to be the effect of holding back the waters and then at long intervals sludging the dams?—The effect then is to cause an accumulation of this sludge on the banks of the stream, banks and bed of the stream, which is a great nuisance when the water has gone down again. That is one drawback; and, again, if the manufacturers use the water below it is a great hardship upon them.

20275. Does any smell arise under such conditions?—Yes, it does when a dam has been sludged.

20276. Then it may be considered that a dam placed on a polluted stream like that is fulfilling, as it were, the first process of sewage treatment?—That is so, to some extent.

20277. Settlement of suspended matter?—Settlement of suspended matter, yes.

20278. If such suspended matter were not let into the stream at all, but were removed on the land, it would have in itself a valuable effect upon the condition of the stream?—Certainly; it intercepts that amount of solid matter.

20279. But the good which has been partly produced by the settlement in these reservoirs or dams is wholly lost by the return to the river of these matters in a putrefying condition?—It is wholly lost, yes; in fact it is much outweighed by the concentrated pollution, I would say.

20280. Then what do you think would be the remedy in the two cases of dams on unpoluted and dams on polluted streams. I suppose in the case of dams on unpolluted streams you would scarcely think it necessary, would you, to insist that the sludge, largely mineral probably, in the dams should be removed on to the land; would you consider that necessary?—Yes, I should say so; I think it ought to be.

20281-2. Mainly on the ground that this mineral matter would deposit in banks on the stream?—Yes, and cause trouble below to riparian owners.

20283. You would not consider that the regulation of the outflow from such dams would suffice, that there should be some regulations, for instance, that the dams should only be emptied at times of flood, not in the summer time or at holiday times, or at times when that addition of suspended matter to the stream would not cause inconvenience to the manufacturers below; you do not think that would meet the case for unpolluted streams?—I am not suggesting that a mill-owner should be debarred from opening his sluice; that I should accept certainly; he has a right to open his sluice, and any solid matter that goes forward through the opening in that sluice must be received below; you cannot prevent that.

20284. *(Mr. Power.)* He must open it in time of flood, must he not?—He must open it in time of flood; well, he may do so; in some cases they must do so.

20285. To make it safe?—To make it safe, yes; that is to say, if any solid matters is taken forward by the water, in the natural way by the flood, that is so much to his benefit. I do not think that you can prevent that. If you do it means that the mill dam may become a serious nuisance.

20286. *(Chairman.)* Then in the case of dams on unpolluted streams, you are of opinion that the law should be modified so as to compel deposit in those dams to be removed on to land and not to be allowed to be pushed forward into the stream?—I think so. The owner of the dam, whether on a polluted or an unpolluted stream, is damming for his profit, and he gets the advantage of it. I think, therefore, he ought also to accept the liabilities which that dam entails, and not to become a nuisance to his neighbours below.

20287. If that is your view in regard to dams on unpolluted streams, clearly it is also your opinion, to a much stronger extent, on polluted streams?—Yes, that is so.

20288. How would it be possible for any arrangement to be come to between manufacturers and local authorities to utilise these mill dams as a first process treatment of those waters in cases where the dry weather flow consists practically of the flow from the sewage works and trade effluents; would it not be possible to call upon each local authority to contribute towards the expense of removing the matters?—To remove the mill dam, do you mean?

20289. *(Mr. Power.)* To remove the contents of a mill dam?—Oh! to remove the contents. I beg your pardon. Well, I should object really to their being used as sewage treatment in the first instance.

20290. *(Chairman.)* Well, but as a matter of fact the deposit of these matters in the mill dam, although an accidental result, is in itself a useful result, if the deposited matters could be removed wholly from the river on to land?—They are returned to the river afterwards; any good produced by the settlement is lost.

20291. *(Mr Power.)* It is sedimentation for the time being?—Yes, quite so.

20292. *(Chairman.)* Therefore, are not the whole population on the banks of the stream interested in its being done, and ought they not to some extent contribute; I merely suggest that with the idea of getting your view upon it?—I do not think you could do that any more than you could ask a community to clean out a manufacturer's tank in which he treats his trade waste.

20293. Then your view is that local authorities ought not to be called upon to pay towards the expense of removing matter out of dams in polluted streams, however valuable such removal might be to the whole population on the banks?—No, I think not; the dams are made by private individuals; they are private property.

20294. Well, we have had your opinion, Mr. Tatton, as to the evils; now, the next point is as to the means of preventing these evils. I think you hold the view, do you not, that suspended matter that has been deposited and has become sludge, and is urged forward into the stream by means of scrapers, or streaming of the water, causes the person who does this to be liable to an offence under Part I. of the Rivers Pollution Prevention Act?—Yes, that is so.

20295. That is your view, is it not?—Under the Mersey and Irwell Act, not the Rivers Pollution Prevention Act of 1876.

20296. The Mersey and Irwell Act is somewhat stronger?—It is somewhat stronger.

20297. But you know that under Part I. of the Rivers Pollution Prevention Act that that is an offence?—No; I do not say that; we have not worked under the 1876 Act, which is the one you alluded to, but under the Mersey and Irwell Act. My experience has been that the Mersey and Irwell Joint Committee Act of 1892 is distinctly stronger. In that Act we have the word "sludge" inserted.

20298. But in the paper you were good enough to send on to us I see this passage:—"Once the suspended matter has been deposited it becomes sludge, and it matters not whether the offender urges it forward into the stream by means of scrapers or by means of a stream of water, he is liable for the offence under Part I. of the Act, and he has no appeal to the Local Government Board." ?—Under Part I. of the Mersey and Irwell Joint Committee Act.

20299. It is Part I. of the Mersey and Irwell Act?—Yes.

20300. I see; under what clause of that Act do you consider that he is committing an offence when he does this?—Under Part I. Clause 2.

20301. Would you read the clause if you have it before you?—I am sorry to say I have not the Act.

20302. Clause 2?—Part I. Clause 2. I have not got a copy of the Act.

20303. On the paper which you have placed before us there is a clause from the Mersey and Irwell Joint Committee Act, 1892; is that it?—That is the saving clause.

20304. The Saving Clause; it is not the clause specifying the offences?—No.

20305. Well, we may, perhaps, come upon it presently. Then I may take it generally in your own area you have had no difficulty in dealing with the evils of dam-sludging; you have obtained convictions in all of these cases where dams were on polluted streams?—Yes, that is so; we have had seven cases, and we have obtained convictions in all cases.

20306. (*Mr. Power.*) There has not been an appeal in any instance?—No, Sir; not in any instance.

20307. (*Major-General Carey.*) And where the water was polluted by the owner after receiving it into the mill dam?—No, it was polluted before it arrived in the mill dam; the owner then sludged out his solid matter into the stream, and we prosecuted him for sludging out the solid matter.

20308. (*Chairman.*) Is Part I. Clause 2 of the Mersey and Irwell Joint Committee Act, in your opinion, a stronger clause than the corresponding clause in the Rivers Pollution Prevention Act, 1876?—Yes; I think it is. We have the word "sludge" in that Act; you will see it is introduced; it was introduced for the specific purpose.

20309. Is that the main difference between the two Acts, that in your Act the words, "or any sludge," are introduced?—That is the main difference. I should define sludge as the result of the deposit of suspended matter.

20310. Then in your Act you have a Saving Clause to this effect, that persons shall not be considered to be committing an offence for putting into such river or stream any sand or gravel or other natural deposit which shall flow there, or have been deposited by the current of any such river or stream?—Yes, that is so.

20311. That is the Saving Clause?—That is the Saving Clause.

20312. And am I right in taking it that, in your opinion, that applies merely to unpolluted streams; to the deposit brought down by unpolluted streams?—Yes, certainly.

20313. Then in cases where you have prosecuted you have obviously not considered that that clause permitted of the sludging of dams on polluted streams?—No; none of the cases that we have taken into Court that we have prosecuted come within that Saving Clause; in no case has that been maintained.

20314. We are anxious to find out whether the condition of the law as it stands is sufficient to prevent the evils connected with the sludging of mill dams on polluted streams. You seem to be under the impression that the clauses of your own Act are so?—Well, so far we have found them; none of our cases have been appealed against; they have all been fought.

20315. Yours is of limited application?—Yes.

20316. Under the general law you think the powers are insufficient?—Yes.

20317. Under the general law you think you want something stronger than this Sub-Section 3; you do not think it should be exempted?—No, I do not think it should; we should want something stronger than that in the case of unpolluted streams.

20318. (*Major-General Carey.*) Do you consider that the sludge should be removed from mill dams under any circumstances, whether the water coming down from the mill dam is polluted or whether it is not—that the sludge should be removed by the manufacturer, and should not be passed into the river?—Yes, I think it should. I think the proper way in all cases is first to reduce the water in the mill dam, and then to remove the sludge on to ground outside the mill dam.

20319. Would manufacturers always have the means of doing it—the means of removing that sludge?—I know of no cases where there would be any practical difficulty in the way of that being done. Of course, it is a matter of cost; it is cheaper for them to send the whole thing down, to sludge the dam only.

20320. Yes, of course; the argument, as I understand it, of the manufacturer is that he receives the water in a certain state, and he discharges the water into the stream in the same state?—Yes.

20321. It has not become worse except by the deposit of the sludge; which has been going on for a considerable length of time; that he is not responsible for the state of the water which he receives in a polluted state; he delivers it back into the stream in the same condition?—Well, he does not deliver it back in the same condition; he accumulates all this filth that is in the stream, all this suspended matter, which perhaps in itself would not cause a serious nuisance if it were allowed to flow past his works in the natural way, and discharges the whole of the accumulation in a short time, making the condition of things very much worse down below, no doubt, for a limited period, but still the evil is greater for that period.

20322. The intervals at which he discharges sludge may be very considerable?—Oh, yes, they may.

20323. Sometimes a year or two years?—Yes, they may.

20324. (*Mr. Power.*) As to the construction of these mill dams—they are commonly made artificially watertight, I suppose; are they concrete, or merely puddled, or what?—Yes, very fairly watertight as a rule.

20325. But they do not concrete them for facilities of emptying them, do they?—As a rule they have a sluice which would have concrete abutments; in some cases they are very roughly made; they only hold the water up in some cases, perhaps four or five feet deep, so that you have not a great weight of water against them.

20326. In other parts of the country there seem to be various methods of dealing with such dams. In some they run them dry—when they have time, I suppose, at their disposal—and wheel out the contents on barrows; and in some, I have seen it myself, they have a flat-bottomed punt with a pole and a scoop at the end of the windlass rope, and thus they dredge out sludge without interfering with the operations of the mill or the pond. Are any of these methods practised in the district within your jurisdiction, or has the sole method in the course of time come to be this sludging process that you have described—driving everything into the stream?—I should say that these systems that you have mentioned are not practised at all; I have seen that done which you have described.

22327. Are those other methods falling into desuetude, do you think, in preference for the method that

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you spoke of?—I think they prefer the method I have described if they are allowed to use it.

20328. A suggestion has been made that some of these people imagine that under the Rivers Pollution Act they have some sort of licence to do this; is there any such impression abroad, do you think, in your district?—Are you alluding to the 1876 Act?

20329. License to get rid of this accumulation in their dam provided they send down nothing more than comes to them?—Well, I cannot say that, sir; I have not worked under that Act at all on the Mersey and Irwell watershed.

20330. (*Chairman.*) You probably are acquainted with the case of the Ribble Joint Committee *v.* Halliwell; does not that bear out the case Mr. Power is speaking about?—Yes; I only know from reading about it; yes, I think it does there; on the Ribble they are working under the 1876 Act; they have not got the extra powers which we have under the Mersey and Irwell Act.

20331. Then may we take it that, in consequence of the successful prosecutions which you have carried out under your Act, owners of dams in your district generally remove all matters from dams on to land?—I think generally they do.

20332. And you think the expense of doing so is not a prohibitive expense; it is found in your district to be practicable to do this?—Yes, it is.

20333. In certain cases you can see it would be somewhat difficult to remove these matters; in a valley with very steep sides, where a road was not available, close to the dam, and so forth. Do you think in many cases, especially with regard to dams on unpolluted waters, that the control of the discharge by the Rivers Board or other authority would be useful control; I mean in regard to times of discharge, and the length of period of stagnation, and so on?—It would be very difficult to work that, I am afraid.

20334. It has been suggested that, for instance, the discharge should not be allowed in dry summer weather?—Yes.

20335. That people should be compelled to discharge at times when the flow in that stream was sufficient to carry matters rapidly forward, and at times when the discharge would not inconvenience manufacturers lower down and so on it has been suggested to us that such control placed in the hands of a supervising authority would in these matters be very useful. Do you think that it would, or is it your opinion that in no case should discharge be permitted?—I do not think it should be permitted; it is very difficult to say; at certain times you may discharge your mill dam and at certain times you may not; it is very hard to regulate them; the inclination of the manufacturer is to do it when he wants to do it.

20336. You think that that kind of control would not be of much value?—I think it would be very difficult to work.

20337. And that the really right thing to do is to prevent the discharge altogether?—I think that is so, yes.

20338. Very well, we might pass on now to another point upon which we are anxious to have your views, and that is as to the possibility of dividing the streams or watersheds into zones, and having standards of purification applicable to each. We felt that you have had a large experience in the administration in your district, and that you have at present, I believe, a sort of provisional standard upon which you act?—Yes, we have.

20339. And therefore your experience is sure to be a very valuable one?—I am of opinion that the standard should be uniform over the whole watershed or administrative area, both from an administrative and also from an equitable point of view. As regards the administrative aspect, given that the standard effluent of the future will be an effluent that, apart from the question of suspended matter, will not decompose in itself, and will not cause any trouble if discharged into an unpolluted stream or into its own stream.

20340. (*Mr. Power.*) That is the minimum of requirement?—That is the minimum of requirement; I think we must have that.

20341. Have you any drinking water streams in your district; streams that are used as a source of water supply?—No.

20342. (*Chairman.*) Would you be disposed to modify that standard in such case?—To make them easier?

20343. (*Mr. Power*). No, a higher minimum ——

20344. (*Chairman.*) Supposing you were discharging into a stream that was used for drinking purposes?—It would certainly have to conform to that standard if it went into a drinking water supply.

20345. (*Mr. Power.*) Would you not have some requirements superadded?—Yes, I think you certainly would require to have something more than that.

20346. You are not concerned with that consideration in your district?—No, we are not; our rivers are too bad.

20347. And therefore your standard has been, so far, with a view to bring people into line?—Yes, it has.

20348. (*Chairman.*) Then where would be the evils in your opinion of having a varying standard applying to different parts of the river or watershed?—Well, having a variable standard would mean that the large towns, which are usually on the lower reaches of the river, would have easier requirements than the smaller towns higher up.

20349. (*Mr. Power.*) Something below what you have just told us?—Something below what I have just told you; that is, I presume, what the suggestion would be, that if you had a variable standard you should have a lower standard for the lower reaches of the river where there is a large volume.

20350. Of course, the Commissioners have made no standard yet, but I think many of us would not like to go behind the standard that it will not allow a putrescible effluent?—That is a very important point.

20351. I speak subject to Colonel Harding's opinion; I think certain of us have a tendency that way, at any rate?—Yes.

20352. Of course, the towns lower on the river, if they had a larger amount than those above of organic matter left in their effluent, might, so long as their effluent was non-putrescent, be allowed that larger amount of organic matter, but I should think the condition of non-putrescibility could not be relaxed?—Yes.

20353. (*Chairman.*) You do not think that the question of relative dilution could be considered as well as the question of relative pollution of the stream itself?—No, I do not think it should. I think that in the first place as regards equity it is fair to expect the large towns to treat their sewage as efficiently as the small towns. What it comes to is this, that the saving in getting a good effluent, in getting an effluent which I should pass as an efficient one; the difference between that point and a lower standard does not necessarily entail a very great expense. In any case you would have the sewers and the outfall works, and probably single contact to pay for, but in order to bring your effluent up to our standard it would merely mean extra filtration, which is a small proportion of the total cost your works have required.

20354. Then we quite understand, now, Mr. Tatton, that in your view variable standards of the kind suggested would not be advisable?—No, I think not.

20355. And that you think an effluent which in itself would be non-putrefactive is essential in all cases?—I think that is essential in all cases.

20356. Well, now, passing on to the question of storm waters, Mr. Tatton, you have been good enough to place before us a valuable report bearing on the storm waters of Stockport, Macclesfield, and Rochdale, and given us the benefit of certain notes and analyses which have been made in regard to those. Now, it is difficult perhaps to gather—I have not had the opportunity of spending much time over this report as yet—it is difficult to get from it any information as to the number of dilutions of sewage which in your opinion should be treated. It was difficult I see to get even accurate information at these various places of what amount was being treated and what amount passed away, and no doubt as yet there is very indefinite and incomplete information in regard to storm waters either as to their volume or as to their composition, but you have in these tables contributed a good deal of information towards that, and we are getting information in other directions. But I gather generally that the amount of storm waters which are being treated, which are here referred to, do not rise above three or four volumes of the dry weather flow?—That is so.

20357. In your district have you many cases of authorities, especially the more important authorities,

that are dealing with the six volumes of the dry weather flow, which we understand the Local Government Board require to be treated?—No, I have very few.

20358. (*Mr. Power.*) Does that mean that their overflows come into operation before the three, four, or five volumes are reached?—Yes, that is to say in the case of Macclesfield, which I have quoted here, the storm overflow comes into operation when the storm water was equalling two and a half times only the dry weather flow. Of course, that did not mean that we got no more sewage down to the outfall works; it still continued to flow down to the outfall works.

20359. But some passed away when it flowed down at that rate?—A certain proportion passed away at that time.

20360. (*Major-Gen. Carey*). Over two and a half times the weather flow?—Over two and a half times the dry weather flow.

20361. That passed into the river?—A portion of it, which we are not able to gauge, passed into the river, and the remainder passed forward into the outfall works.

20362. (*Mr. Power.*) In a case like that, Mr. Tatton, however stringent your standard might be for what passed through the whole "treatment" process a considerable amount would be allowed to go into the stream which should not go there?—Oh, yes, that is so, and the trouble is that storm overflows do a great proportion of the harm in the summer time; if you have a sudden thunderstorm in a hilly district, the water will flow down the sewers with great rapidity, and even if you fix your overflows, say, at six times the dry weather flow, it may go over these overflows in very large volumes into the river at a time when the river is low and cannot deal with it—cannot carry it forward.

20363. This might occur in a fraction of the 24 hours?—In a fraction of the 24 hours.

20364. And you think the volume might be very large that so passed over in a short time?—It might be very large indeed.

20365. (*Chairman.*) But evidently you think that storm waters beyond six times the dry weather flow are still polluting?—Oh, there is no doubt about that.

20366. And do you think that, say, 10 or 20 times diluted, there would still be pollution carried to the stream?—It depends on the place entirely; you must take each place on its own merits. If you have a hilly district you want your overflows at a higher level than in a flat district, because the sewage finds its way down to these overflows much quicker than it does in a flat district; it rushes down from the overflow into the river; whereas if the district is fairly flat it takes a considerable time and is more equalised, and you get more sewage down to the outfall works and less over the storm overflows.

20367. (*Mr. Power.*) In the speedy operation of the storm-overflow you would get the first washings of the storm, which are perhaps the most objectionable?—That is exactly the trouble; they are most objectionable.

20368. Have you made any attempt in your area to regulate the point at which this, that, and the other overflow of a town sewer should come into operation?—What we do is not to suggest a volume, but if we find the overflow is apt to offend periodically we make complaints about that overflow and have the sill raised, and I think that is really the way to tackle the difficulty.

20369. (*Major-General Carey.*) To raise the sill?—To raise the overflows until you find that they do not come into operation when the stream is low. Of course, we admit that at times of very heavy rain you must have on our rivers which are not used for drinking purposes—there must be some overflow.

20370. Is the dry weather flow calculated on the average of the 24 hours, or on the maximum in a day?—It is on the maximum; the average maximum flow—that is to say, taking each day, you take the maximum flow of each day, and you take the average of these days, and dilution is calculated on that maximum, on that average maximum; that is to say that it would be considerably more than the average dry weather flow of, we will say, six o'clock in the morning; the maximum flow is probably about 12 o'clock in the day; two and a half times dilution at 12 o'clock would mean very many more dilutions at six o'clock. What I mean is this—that supposing your overflow is at a fixed level and it comes into operation, it may be when the sewage is diluted up to a volume of two and a half times at midday, it would not come into operation when that sewage was diluted up to two and a half times at six o'clock in the morning.

20371. No, there would be less volume passing through the sewer?—There would be less volume passing through the sewer, yes.

20372. You take the average of the maximum?—Yes.

20373. (*Mr. Power.*) The average of the highest dry weather flow at noon.

20374. (*Major-General Carey.*) How do you get the average?—We take it over a period of six weeks and during dry weather in the summer.

20375. Then, I notice, to take one of these places, mentioned in the Report which you have made to the Commissioners on sewage flows, that, in 1902, the flow reached six times the dry weather flow—five times, four times, four times, four times, six times, five times, four times, seven times, six times, five times, four times; so that there are a large number of cases where it has exceeded three times?—Yes.

20376. At least, in which it has exceeded the three times?—Yes, but I must explain that. In that table the rates are worked out on the dry weather rate of that particular hour. For instance, if you take Table A1—take March 22nd, 1902—the time of the storm was between 12.20 and 1.40, that is 1 hour 20 minutes; the rates of dilution were six times for 20 minutes, five times for 45 minutes, and four times for one hour. That is the actual time the storm took place.

20377. Yes?—That is the night flow, you see; and, therefore, those dilutions would very soon be reached, because they are taken for the particular dry weather rate at that hour.

20378. It would be the sewage running at its minimum then, between 12.20 and 1.40 a.m.?—Yes, it would be.

20379. On the 25th, 1 o'clock a.m.—that would be the same thing, "early morning eight times"?—That is the same thing.

20380. (*Mr. Power.*) Given a minimum standard that the effluent should attain to, I rather gather that you are disposed to consider that it may be necessary to fix by authority the level at which overflow at the weirs on sewers should take place for each town; and not only at the outfall works, but on the several sewers of the town according to their gradients?—Yes.

20381. It would have to be done by an authority, which would have regard to the total flow of the river, I suppose, and the amount of purification effected on that part of the sewage subjected to full treatment, as well as to the liability to overflow at the weirs?—Yes, that is so; the whole system should work together. All the overflows should be regulated, whether in the towns or at the outfall works, to conform to whatever the requirements are.

20382. But then, if you have a uniform standard which must be observed, it seems to me you must have separate regulations at each place as regards the overflow weirs, and not only on the outfall sewer, but on a number of sewers; it would amount to that, would it not?—Well, your standard would not refer to the condition of the storm water, but to the volume.

20383. Yes, it would affect the volume that would pass away?—Then it would vary.

20384. If you are dealing with two and a half or three volumes completely at the outfall works, and you have liability through the position in which the weirs are, not only that on the main outfall sewer but on other sewers, that anything beyond this will pass away in greater abundance in the storm when you get six, seven, or eight times that of the dry weather flow for a short time, you may have to put these weirs higher. But would not that mean you would have to apply a general principle in each particular instance in the town?—Yes, that is so.

20385. (*Major-General Carey.*) You would have to rely on the local authority to raise their weirs?—Yes, with inspection. Supposing we found one overflow in the town came into operation before the others, we should then complain to the authority and get that overflow raised. It would have to be done by inspection, but there is no difficulty about that; we do it now to a great extent; we have had a great number of overflows raised that were serious offenders.

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20386. Those in which compulsory action has really been taken by the Rivers Board?—Yes, that is so.

20387. (*Chairman.*) I have one or two more questions which I ought to put to you, Mr. Tatton; and one of the most important things we should like to know from you would be your opinion as to the number of dilutions it would be proper to ask the local authorities to treat. I notice in the table you have placed before us that when a volume of dilution has reached four, you have it by the analyst's evidence that such storm waters are really more polluting than the dry weather flow of the sewage?—Yes, that is so.

20388. Therefore, clearly, if the consideration to guide us is to be the number of dilutions which produce so small an amount of pollution that it may be left to the self-purification action of the stream to get rid of it, we should have to fix the standard at a great many volumes of dilution, should we not?—You would in certain cases, no doubt.

20389. There might be exceptional cases where it might be more or less, but, speaking generally, you would have to fix the number of dilutions to be treated, if that was the only matter you were considering, the proportion of dilution, you would have to fix it very high indeed—10, 20, 30 dilutions, something like that?—I do not think it would be as high as that. But in cases of towns with hilly sides it would undoubtedly be higher; but, of course, it is the rate of flow we are speaking of now; that does not necessarily mean so many volumes to be treated at the outfall works; for instance, supposing you fix your overflows eight times the rate of dry weather flow, it does not mean that you would have eight times the dry weather volume discharged at the outfall works; it might only come up to that eight times say for an hour, and then go down again, and your volume perhaps would not be more than five.

20390. I quite appreciate that; but suppose we were merely to be guided by the question of pollution of streams, should we not necessarily have to fix the number of dilutions before which storm overflows should come into operation at a very high level? Clearly, then, six dilutions would not suffice, because I notice in one of the analyses of the Macclesfield storm water that the oxygen absorbed from storm waters over six times diluted was 37 parts per 100,000. Whereas in the dry weather sewage of Macclesfield it was only 4·35?—Yes.

20391. In settled sewage; and you may take it probably it would be 9 or 10 parts in the absolutely crude sewage?—Yes.

20392. So that really at six dilutions we had here storm waters, which, as measured by the oxygen absorbed, were three times as bad as the dry weather flow of sewage; therefore, clearly six volumes would be insufficient if we are to be guided simply by the idea of preventing the pollution of the stream?—It would.

20393. Then is it in your opinion practicable to call upon any authority to deal with such a number of dilutions as should prevent pollution of the stream?—I should not like to say that. I think it would not be a hardship to call upon authorities to treat six volumes.

20394. It would not be a hardship to call upon them to treat something more than six times?—I do not think you would require to treat many more than six times.

20395. You think it is impracticable for them to treat more than six times?—Well, it is all a matter of cost obviously. In some cases it may entail extra sewers.

20396. What I want to get at, Mr. Tatton, is this; must we be guided by that which is financially practicable, or must we be guided by the question of the pollutions of the stream. It would seem to me from the data which you have placed before us that the number of dilutions would have to be very great before you would allow storm waters to come into operation, if you were to be guided alone by the question of pollution of the stream?—Yes, I think they would.

20397. And therefore you would probably consider a more or less empirical limit, the limit of what is financially practicable?—Yes, clearly.

20398. Is that your view; I am very anxious to get your view?—It must be fixed so to some extent.

20399. Do you think we must be guided by what is financially practicable in this case, and that it is not possible to reach the treatment of so large a number of times as would really stop any serious pollution of the streams?—I think that where a town is situated so that its storm water does seriously pollute the stream it is right to call upon that town to increase its outfall sewers if necessary, because that is where the expense would come in in order to prevent that pollution.

20400 But you must be guided, must you not, by what is financially possible?—Yes, clearly we must.

20401. What is, then, your opinion of the provisional regulation which I understand is applied by the Local Government Board at the present time; it, I understand, requires that six volumes of the dry weather flow should be treated; some of them fully and some of them partially; do you think that that is as far as is financially practicable for local authorities to-day, and do you think it is practicable for them to go so far?—I think, on the whole, that that is a very fair requirement to ask them at the present time. I think in certain cases where they do seriously pollute even with that volume taken down to the outfall works that they should be required to go to extra cost in consequence.

20402. You mean it is reasonable not to ask them to deal with more than six volumes in any case?—I think it may be in some cases. It is very hard to lay down a hard and fast rule; as I have said, I think you must take each case on its own merits. If the town seriously pollutes, periodically, in summer, a clean river, we will say by storm water, it seems to me fair then that you should ask that town to go to more expense than another town in which the conditions are different in order to prevent pollution.

20403. Then would you in such cases ask them to deal with more than six times?—You might.

20404. How many more would it be practicable to deal with?—I cannot say that at all.

20405. As a fact have you any considerable authority in your district which does deal with six?—No, I have not.

20406. Have you any which is proposing to deal with six?—Manchester is proposing to deal with six.

20407. (*Major-Gen. Carey.*) Not to fully treat six volumes, but I suppose to treat a certain proportion of six volumes,—say, three volumes—as sewage; and the rest to be treated in a necessary reservoir?—Not effectually; no, sir; I do not say that; what you want to do chiefly is to remove the suspended matter from the storm water.

20408. Yes; that is the trouble. It is the suspended matter which settles on the banks of the streams and causes a nuisance afterwards.

20409. (*Mr. Power.*) Is not one of your points this; that it is not so much the six times the volume of the dry weather flow you are considering, but you think that in certain times of storm, when sewage is coming down at the rate of above six times the dry weather flow, something must pass away into the river that should not go there, and that accordingly you would prefer that the sill of the overflow was put higher in certain instances; that it should not overflow until, say, a rate of 12 times the dry weather flow was reached, you being in expectation that at the end of the 24 hours you would not have got more than six times the volume of the dry weather flow delivered to the works?—Oh, certainly, that is so.

20410. You would not allow the overflow to take place so early as at six times the rate of dry weather flow on the expectation of that, although raising the sill would entail more coming down to the works at one time of the day. You would not by the time the 24 hours had expired have had more than the six times flow to deal with at the outfall works?—Quite so. You might have a considerably larger rate of flow than six volumes.

20411. Yes, at the end of the day?—A total volume of not more than three or four.

20412. I think that was your point that you think more passed into the river in time of storm than you think right should go?—Yes.

20413. A higher overflow weir does not necessarily entail the authority dealing with six or seven times the dry weather flow at the outfall works?—No, it is more a question of sewers; it entails carrying more forward to the outfall works.

20414. That rather leads back to what I was asking you before. Does that not mean that these overflows must be fixed by authority in the particular instances?—Yes, by a rivers authority.

20415. As the Chairman was suggesting, they may as a result have to treat more than six times the dry weather flow?—At the rate.

20416. It might work out in over six volumes, but in a good many instances you do not think it would?—No.

20417. They would have, of course, to accommodate during storm, a larger amount than the sewers will accommodate at present?—Quite so, but the actual volume which they would have to treat would not necessarily be more than six volumes of the dry weather flow for the day.

20418. The volumes they would have to treat in the course of a month would not exceed six times the dry weather flow for a month we will say?—Oh, no, certainly not; nothing like it.

20419. It is the storm water that you are most uneasy about from the rivers point of view?—Yes, that is so, it causes most serious trouble in the summer.

20420. (*Chairman.*) In most cases the sewers are not large enough to carry anything like six to twelve volumes of the sewage, are they?

20421. (*Mr. Power.*) It would mean reconstructing the system of sewers; the outfall sewer at any rate?—It would do in some cases, but I think at the present moment the Local Government Board insists on their treating that.

20422. Extra tanks for receiving extra storm sewage?—Yes; a very good way of dealing with it.

20423. (*Chairman.*) In Manchester they are proposing to deal with six volumes; are the main sewers at Manchester at the present time capable of dealing with six volumes?—No, they are not.

20424. Therefore it would mean additional sewers?—Yes.

20425. Greater additional expense?—Yes.

20426. Is Manchester prepared to go to that expense?—They are looking to it; we are complaining to them of their storm overflows.

20427. (*Mr. Power.*) They revised their system of storm overflows five or six years ago?—Yes; they have many overflows in the town, which come into operation, much below that six times.

20428. (*Chairman.*) Although, as Mr. Power pointed out just now, the storm waters may only come down for a limited period, still if you are, during such limited period, effectively to deal with those storm waters the plant at the sewage works must be adequate?—Yes, that is so.

20429. Therefore at times when your overflow is not passing you would have a plant greatly in excess of what is required during dry weather?—That is inevitable; you always have that at works.

20430. Clearly, to do it it means for a short period it might be desirable to treat, as Mr. Power suggested, above six, say, up to 12 volumes. You could not do it unless you had first of all sewers large enough to bring such volumes to the works; and, secondly, a plant large enough to deal even for a short time with these volumes?—That is so.

20431. Therefore, we come to this, what is financially practicable to be done; and do you think that the existing provisional regulations in regard to the question of dilutions are fair; should they be exceeded; should they be diminished, or what?—Six times the volume.

20432. Yes.

20433. (*Mr. Power.*) Do you think that if the overflows were universally fixed at six times the rate of dry weather flow, which they are not now, a very great deal might be gained, and that taking it on the whole what went over would be negligible, or do you think some further consideration needs to be given to this question?—In certain cases six times would not be sufficient.

20434. At present I suppose very few towns in your district have a rigid standard of six; they are below, are they not, very generally?—Yes, they are below it very generally.

20435. Supposing universally throughout your watershed no overflow were allowed until a rate of six times the dry weather flow was reached, would not a very great deal be gained, do you think?—A great deal no doubt would be gained.

20436. But you do not think sufficient?—But we would still have pollution in summer in thunderstorms.

20437. Heavy downpours?—Yes, principally in Macclesfield.

20438. You would like these heavy downpours impounded and dealt with before going direct into the stream?—Yes.

20439. (*Chairman.*) Referring once more to your opinion that six dilutions which are now required to be treated are a fair quantity to expect the authority to deal with, why do you think that six rather than five or seven would form a proper basis?—You must take something as a basis to work upon. I do not say that six times will do in all cases at all; I think in some cases it might be varied.

20440. I understand this is your view, that many times more might still be called pollution?—Yes.

20441. What we are trying to get at now is what in your opinion is financially practicable in your district. I understood you to say that this six times was a fairly practicable thing to require?—I think it is fairly well accepted as practicable in my district.

20442. Would it be practicable to go further and ask for more dilutions to be treated?—In certain cases.

20443. Do you think it would be financially practicable?—It is very difficult to answer that question, because it depends upon the financial condition of the town to a great extent.

20444. The condition of its sewers?—The condition of its sewers; they might have to lay new sewers entirely for it; they might be in great financial difficulties, and could not afford to lay new sewers.

20445. Meantime we may take it as your view that it would be reasonable to ask the local authority to deal with six dilutions, some of them fully and some of them partially?—Yes, I do.

20446. Well, now, as to such partial treatment, I notice that in many of the cases that you have brought before us these storm waters are actually worse, more polluting than the dry weather flow; that is so, is it not; it is also in harmony with our experience elsewhere?—Drs. Houston and McGowan have made the analyses; I am answering on their analyses; I am not a chemist.

20447. Dr. McGowan, may I take it that is so?—(*Dr. McGowan.*) Yes, in some cases.

20448. I will tell you the point that seems to us to be very interesting to get at, is your highly polluted condition more largely due to suspended matter than to dissolved impurities in the case of storm waters?—(*Mr. Tatton.*) That is a very important point which I am not able to answer; that, I take it, is a chemical question.

20449. That is a point which we shall have to ascertain from Dr. McGowan?—I think it is a very important point to ascertain.

20450. If it were found, as appears to me not at all unlikely, that the impurities of storm waters are much more largely in suspension that in solution, then that would point, would it not, to the necessity of the partial treatment of storm waters being directed to the settlement of such suspended matters?—Yes, it would.

20451. Have you generally been able to form an opinion whether the settlement of suspended matters in the storm waters does result in giving you an effluent which is fairly free from dissolved impurities?—I cannot tell you that, but I can say that a comparatively short period of settlement of storm water effects a very great improvement. The suspended matters in storm water seem to precipitate more rapidly than the suspended matters in ordinary sewage, and I have no doubt that it is the suspended matters in storm waters that do cause trouble, because they settle on the banks of the stream.

20452. I am interested in hearing that opinion from you, because it is in harmony with the opinion we have heard from several others who have had practical knowledge of these matters that the suspended matters in storm waters do settle more rapidly than the suspended matter in the dry weather flow?—Yes, that undoubtedly is the case.

20453. Then you consider that point is one which it would be very important for us to investigate?—Yes.

20454. As to the relation between the suspended and the dissolved impurities in storm waters?—I do.

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20455. (*Mr. Power.*) I suppose you have never seen, in any part of your district, any contrivance adjusted to the storm overflow, something in the nature of a rough filter, so as to pass the early overflow in a storm through some sort of a filter or a strainer, have you?—No, I have not.

20456. Something might be gained, possibly, from an engineering point of view, by putting small filters or strainers on the overflow. Has it been attempted, do you know?—No, it never has, as far as I know. I am afraid the difficulty would be that you would so soon get the filter clogging up.

20457. It would want constant attention; it would probably want renewing, or turning over, after each storm?—Oh, yes; I am afraid the first rush of the storm would block it up.

20458. It would necessarily have to be of small area, because such strainer would probably be in the position where it could not be large?—Yes; however, I have had no experience of it practically.

20459. (*Chairman.*) There is just one other important question I should like to ask you, Mr. Tatton; and that is, when we spoke just now about dealing with six volumes of the dry weather flow, and when you expressed generally an approval of that empirical limit, we should understand, of course, that you would consider that that cannot be a fixed limit applicable everywhere. There must be instances where obviously it must be modified. For instance, in the case where you have sewers bringing down a considerable amount of subsoil water, so that the dry weather flow in those cases is abnormally high, it would in such cases be unfair, would it not, to call upon an authority to deal with six dilutions not only of its domestic sewage, but of this subsoil water? Let me take another case. Cases where you might have in sewers a considerable amount of trade effluents, consisting, say, to some extent of innocuous discoloration; it would perhaps scarcely be fair to require that such trade effluents should be dealt with in six volumes of dilution, in the same way as the domestic sewage. Then take yet another case, where one authority had an abounding water supply and another authority had an insufficient water supply; you might have a consumption of water in the one case of 25 gallons and in the other of 50; it would perhaps scarcely be fair to call upon the authority which had an abounding water supply to deal with six times the dry weather flow in the same way as you call upon the other authority with the inadequate water supply also to deal with six volumes. Does not that lead us, therefore, to this point, that it might be necessary in fixing the volume which is to be multiplied by six to take so many gallons a head as the basis? What do you think about that?——

(*Major-General Carey.*) I think that is really shown in the Local Government Board provisional rules; it is six times the dry weather flow of sewage.

(*Chairman.*) Based on volume per head.

(*Major-General Carey.*) Of sewage proper, the trade water being absolutely separated; you do not multiply the total by six.

(*Chairman.*) Can you tell us what is the basis which they take; is it 25 gallons per head, or what?

(*Major-General Carey.*) The basis is the actual dry weather flow, based very often on their water consumption. The authority are able to state their own dry weather flow.

(*Chairman.*) Is there any allowance made where there is an abundant water supply and where there is a deficient one?

(*Mr. Power.*) I do not think there is.

(*Chairman.*) The point I want Mr. Tatton's opinion on is this. I understand he considers that it is fair to call upon an authority to deal with six times its dry weather flow, but I want to know whether he thinks the volume of the dry weather flow should be any volume arrived at by multiplying the number of the population by a certain reasonable figure of water supply which should be constant in all cases?—I should be inclined not to make a hard and fast rule, and not to fix it definitely at any amount of dilution; that is to say, that each case should be judged on its own merits; and I should be guided to a great extent by the result of the analyses of the sewage.

(*Mr. Power.*) You take as a basis the strength of the sewage, do you mean?—I mean that supposing you have a very weak sewage with a large amount of subsoil water, if you dilute that down you might possibly—I will not speak from the chemical point of view—arrive at an effluent which would be non-polluting from our point of view.

20460. (*Chairman.*) Then we are to take it that your rule of the six volumes being a reasonable amount requiring to be treated is a general view?—That is it.

20461. And you would modify it and be guided in specific cases by the condition of the sewage itself?—Yes; I should take all the circumstances of the case into consideration, and I should not fix it by statute at six times, and I should not allow it to be an answer to a charge of pollution. If an authority were polluting a stream, although treating six times the volume, I think that they should still be held liable, and that the fact that they are treating six volumes should not be an answer to a charge of pollution.

20462. Then you seem to be in favour of having no fixed rule in regard to the dilutions?—I should only have a professionally fixed rule, the same as we have with our standards. It is only a provisional standard to see how it works; in certain cases we should have to go beyond it.

20463. Mr. Willis calls my attention to this, that it would be very inconvenient to have a constantly varying standard. If an authority proposes to carry out a scheme, and you fix a number of dilutions, and they construct their sewers to suit them, it would be extremely inconvenient if shortly afterwards you raised the number of dilutions to be treated, so I think it is rather important that we should get at the opinion of a large authority like yours as to the number of dilutions which it is prepared to ask them to treat?—But the increase of population itself would create the same difficulty. Supposing they construct their sewers to deal with six times the dry weather flow now, in a few years' time these sewers would be too small; in any case they would have to have a margin.

20464. Evidently, but a wise authority would look ahead, would it not?—It would look forward.

20465. And in laying down its sewers, would consider what has been the expansion of its population in the past, and form some opinion as to what it would be, probably, say in 20 years, in the future?—Yes.

20466. (*Major Gen. Carey.*) There is one point I wish rather to get cleared up. The Local Government Board Provisional Regulations on the subject refer to the average dry weather flow of sewage in 24 hours?—Yes.

20467. Your dilutions are based on a maximum flow in the 24 hours?—Yes, that is so.

20468. Therefore, practically the amount, six dilutions of sewage in 24 hours on the Local Government Board basis, would mean far less a volume than on the basis that you mentioned?—Certainly, it would.

20469. Therefore, supposing a place provided for six dilutions of sewage on the 24 hours average it would probably and almost certainly be providing for a very much less dilution than on the maximum in the 24 hours?—That is so.

20470. That ought to be taken into consideration?—That ought to be taken into consideration. That is a very important point.

20471. All your answers on this question have been based on the maximum flow in the 24 hours?—That is so. For instance, if we take the Stockport returns, dilutions of 3, 4, and 4 times.

20472. Yes?—Whereas the actual discharge to the outfall works was only $2\frac{3}{4}$ times the average dry weather flow.

20473. In the 24 hours?—Yes, in the 24 hours; we have been speaking all through as regards the rate of flow.

(*Chairman.*) It only remains for me, on behalf of the Commission, to thank you for the great trouble you have taken in getting up these data for us, and in coming to day to give us your opinion on these important points. We are very much obliged to you.

Mr. E. HALLIWELL, called; and Examined.

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20474. (*Chairman.*) You are the Chief Inspector of the Ribble Joint Committee?—I am, sir.

20475. You have been good enough to come here to-day for the purpose of enabling us to get your opinion in regard to various matters. In the first instance, in regard to the evils that are produced by the sludging of the mill dams. Would you be good enough, in your own words, to tell us the nature of these dams in your district, whether they are situated mainly upon polluted or unpolluted streams, and the nature of the evils that arise from dam sludging in either case?—The dams, sir, in the Ribble Watershed are situate, as a rule, on polluted streams. They are of various sorts, constructed in different ways. Some of them, although on polluted streams—I ought to say that they discharge into polluted streams—collect the waters from small tributaries which are clean streams. Another class of mill dams are those which take in polluted waters, and are made in the manufacturers' works. Another class which is very prevalent in the watershed is that class which on a polluted stream is made in the bed of the stream, the manufacturer places a weir below the end of his works, at least as near as convenient, and, in some cases, dams up the river for a very considerable distance. The distance will vary according to the nature and fall of the river. The methods of sludging of dams are very variable. We had one case some few years ago where a manufacturer wished to clean a fresh water dam. Previously there had been a case taken into Court, and it was held that a manufacturer is permitted, under certain circumstances, to sludge his dam. The firm, to keep within the law, instead of sending men in with rakes or spades, connected pipes to the water supply, and after running off the top water from the dam they washed in from the bottom the accumulated matter by the force of water which they obtained from their hose pipes; they therefore managed without sending anybody into the dam to get rid of the whole of the accumulated matter. That is one form of sludging of fresh water dams. I will give you examples of the sludging of other classes of dams. On the River Darwen, one of our main streams, there are a very large number of dams which are sludged in some cases once or twice a year, generally at holiday times, and in other cases once or twice a month. The top water is first run off, and then the whole, or part of the river, is diverted through the dam. The large volume of water removes a large amount of sediment; but if the whole has not been entirely removed, the water is diverted by means of boards or planks into a fresh portion of the same dam. The force of water removes still more of the sediment, and with a little management the whole of the deposited matter is washed out into the stream.

20476. I suppose it does not really very much matter what process they employ to get rid of it, whether washing it out with the water supply by means of the hose, or pushing it with spades or rakes, or washing it out by diverting the river into it; it all comes to the same thing; it is washed out of the dam into the stream?—It is washed out into the stream.

20477. Now, does any evil arise from that?—Yes, sir; the streams are, when this is going on, extremely foul. Some distance below the dam you will find that the river is in a most polluted condition. On Saturdays it is quite a common occurrence to find the river on a Saturday afternoon, from 12 o'clock till late, according to the position you are taking up on the river bank, you will find the river black, and in the summer months stinking.

20478. There is a great excess of suspended matter for one thing?—Yes, that is so.

20478*. You have, I think, given us some data and analyses which have been made under your direction, in which we find, for instance, that the river Darwen, above Scotshaw Brook Mill, had nominally about four parts per 100,000 of suspended matter in it, but below the dam, during sledging operations the river Darwen had 244 parts per 100,000?—That is so, sir.

20479. So that there is evidently an enormous increase in the suspended matter?—Yes.

20480. It is not only that there is a great increase in the suspended matter, but I suppose it is the character of the suspended matter which adds to the objection?—That is so.

20481. The suspended matter being in a putrefying condition?—That is so. I should like to make a correction here; in the case you have mentioned, Scotshaw Brook, it was not exactly a dam, it was a goit, and goits are very similar in their action to the dams. From the point of intake to the point of discharge is a distance of about 300 yards, but the goit continues to a mill, a distance of half a mile.

20482. I suppose suspended matter settles in the goit, and when that suspended matter becomes inconvenient in volume it is let out?—That is so.

20483. So the action of the goit is only differing in degree from the action of the dam?—That is so.

20484. Now, as to the extent of the nuisance, there is obviously a large increase of suspended matter; is there are no appreciable stink from a discharging dam?—Yes, sir, there is undoubtedly.

20485. Have you had any complaints?—We have had informal complaints from manufacturers; they say the river is always very bad on Saturday; they do not care to write and make a formal complaint—they make these complaints to the inspectors when they visit. But in addition to that there has been a very bitter complaint. It has not been forwarded to us; I believe the letter has been sent to the Local Government Board—of that I am certain. But the Wigan Borough suffers very severely from this same sort of thing, running off the top water of mill dams, which carries away a lot of the suspended matter. The papers nearly every week contain letters, and remarks are made in the Council meeting nearly every meeting during the summer of the condition of the river, and that, I am confident, is entirely due to the running off of these mill dams and the removal of this suspended matter in this way.

20486. Then we are to take it from you that you have had complaints, many complaints, and that you are satisfied that it is a very real evil?—I am, sir.

20487. Now you have attempted to remove it by bringing actions against certain persons, and notably there is the case of the Ribble Joint Committee *v.* Halliwell, is there not?—Yes, sir.

20488. What was the result of that litigation?—The case was dismissed, sir; it was held that no offence had been committed.

20489. The case was appealed against?—The case was appealed against.

20490. And the judgment was confirmed?—And the judgment was confirmed.

20491. Now, what were the grounds of the dismissal of the case?—The grounds were that the matter was matter in suspension and not solid matter, and therefore the section of the Act——

20492. Which Act?—The Act of 1876.

20493. The Rivers Pollution (Prevention) Act?—Yes.

20494. Is there an exception made in regard to the matter in suspension coming down the stream?—Yes, sir.

20495. Do you happen to remember where it is?—It is in the Definitions, sir; "solid matter shall not include matter in suspension."

20496. Well, any way, there is an exception which appears to permit of this being done?—That is so.

20497. The existing law, therefore, you found to be insufficient to enable you to prevent the evils arising from dam sludging?—Yes, sir; also it was held—Judge Coventry stated that if he were wrong on this point of it being matter in suspension the firm were entitled to do it under Section 17.

20498. I see the section says that the Act shall not apply to or affect the legal exercise of any rights of impounding or diverting water?—That is so.

20499. Then Judge Coventry in this case held that that permitted these persons, even if there was pollution by dam sludging, to hold up the water?—That is so, and that was confirmed in the High Court.

20500. Then clearly you found that under the existing law you are unable effectively to prevent this?—That is so.

20501. You do not find the manufacturers are disposed to submit themselves to control as to the times of

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discharge, and so on?—No, sir; we have not pressed them to do that.

20502. But, any way, you have been unable to get them to remove from their dams the deposit in such a way as it shall not go into the stream?—That is so.

20503-4. What modification of the law in your opinion would be required and would be justified by the circumstances?—I think, sir, that one might reasonably ask at least that the law should be that when the top water from the dam has been run off, the matter which does not run off with that top water should be removed. You can run off your top water and leave a very great deal of the sediment at the bottom of the dam. The sediment, to my mind, should be removed in some way other than by the river.

20505. It should be put on to land, I suppose, carted away or taken away, or removed by some means on to land?—That is so.

20506. And is that, do you think, financially practicable in most cases?—I think so.

20507. Do any of your people in fact do that?—In one case, sir, they do indirectly; they do not do it in exactly the same way, but we have one case where there is a large dam. For reasons—the size of the dam and the difficulty of filling that dam again—they are unable to run off the top water, and frequently during the year a man removes the suspended matter from the bottom of the dam.

20508. Without emptying the dam?—Without emptying the dam.

20509. Does he do it by means of a boat?—He does it by means of a large raft, and by scooping the sediment from the bottom of the dam.

20510. On to the raft?—On to the raft, and then that is removed on to the land. That is done I do not think necessarily to suit us, but because of their own convenience.

20511. (*Mr. Power.*) Is this stuff supposed to have manurial value when it is recovered in that way, or has it simply to be got rid of as detritus of no worth?—I should think it would have very small manurial value.

20512. Do they use it as top dressing for pasture?—No, sir; I do not think it would be even worth that.

20513. (*Chairman.*) The fact that a certain firm is able to do this, and it is not found to be a ruinous expense, leads you to think that it would be a fair thing to ask all dam owners to deal with sludge in the same way?—Yes, sir.

20514. You think that is really necessary?—I do.

20515. You do not think that the mere controlling of the manner and times of the discharge would be sufficient?—You are bound to have a nuisance, sir, in any case, even if you control it. In the case of dams which are situate in the stream, which are built in the stream, to my mind it is impossible to insist on the removal of the suspended matter, because the matter settles in the river bed. Even if he runs off the top water, he cannot send a cart in to remove the sludge; he will do it at the time when there is heavy rain, when the river is coming down in more or less flood; it will remove the sediment, and even if the men were willing to have the means of removing it, the river coming down in volume would prevent them doing so, so that they would naturally, I take it, run off their top water at times when there was likely to be a flood; then the river coming down would remove the accumulated sediment in the dams, those of the dams which are situated in the river bed.

20516. In those cases you think it is not practicable to insist upon the persons using them removing out of the river altogether this suspended matter?—I think it is impracticable.

20517. It is impracticable in most cases?—Yes, sir.

20518. And in those cases would you do anything in the way of regulation?—I should.

20519. You think that would be useful?—I think it would be necessary, sir.

20520-1. You think at present, in the absence of any special clause in your own Act, the law does not allow you to prevent the evils of dam sludging, but the law should be modified with the view to permit two things—the control of the discharge, and the absolute removal in certain cases of the deposited matter on to the land?—That is so. Might I point out, sir, while you are speaking of the evils of sludging, that the table which I have submitted shows more clearly than the case of the Scotshaw Brook the evils of dam sludging.

TABLE referred to by MR. HALLIWELL.

RESULTS IN PARTS PER 100,000.

STREAM STATION.	Time.	Total solids.	Solids in suspension.			Solids in solution.			Ammonia.		Oxygen absorbed. Total.		Oxygen absorbed in solution.	
			Loss.	Ash.	Total.	Loss.	Ash.	Total.	Free.	Albuminoid.	15 minutes.	4 hours.	15 minutes.	4 hours.
River Blakewater -	9.0 to 11.30	46·8	·8	·0	·8	12	34	46	·2	·05	·4	·9	·36	·6
Do. do. -	11.30 to 1.30	55·2	3·6	5·6	9·2	14	32	46	·21	·095	·7	1·56	·42	·68
Do. do. -	1.30 to 3.0	59·0	10·8	9·2	20·0	13	36	49	·26	·172	1·16	4·24	·56	1·16
River Darwen -	9.30 to 11.30	68·6	3·2	2·4	5·6	21	42	63	·28	·21	1·34	3·2	1·02	2·18
Do. do. -	11 30 to 1.30	100·6	19·2	20·4	39·6	18	43	61	·29	·25	3·08	7·94	1·44	2·68
Do. do. -	1.30 to 3.0	63·7	2·3	3·4	5·7	14	44	58	·29	·23	1·3	3·18	·9	2·14

20522. (*Chairman.*) Yes?—In that case the samples were taken over a period of two hours, and you will note that the average suspended matter was 5·6. Then samples were taken from half-past 11 to half-past 1, two hours again, and during the whole of that time the average for that time the suspended matter was 39·6. The oxygen test you see shows that the figures increased from 3·2 to 7·94, showing that the suspended matter does contain a great deal of organic matter. Then from half-past 1 to 3 o'clock the river has again come back to almost its normal state, a very large decrease in suspended matter, and the oxygen absorbed is very much the same as it was early in the morning.

20523. So that during the sludging of the dam the suspended matter in the river was increased about eight times in the case of the River Darwen?—Yes, about eight times.

20524. And considerably more than that, about 20 times, in the case of the River Blakewater?—That is so; and, of course, one of the main evils in this case, the Blakewater and the Darwen, is the fact that after it has passed the district where these dams are situate, some few miles below the stream you have weirs built in the streams, and this large accumulation of suspended matter which has come down settles behind these weirs and gives rise to a very great nuisance.

20525. Then I will pass on, Mr. Halliwell, to ask your views in regard to the possibility of dividing streams or watersheds into zones, and having different standards of purification applicable to each. Do you think that variable standards applicable to different conditions and different parts of a stream or watershed are desirable?—I do not, sir.

20526. Will you tell us why?—I think that it would be as easy and as practicable for a Rivers Board or any other authority to judge each works on its own merits, as to form different zones on one river, or put rivers into different zones. The conditions are so very, very variable. The volume in some of our cases of the river in dry weather is almost entirely manufacturers' effluent or sewage effluent. After a little rain one river is washed out, and that rain is felt for some days. In another river after dry weather almost the same amount of rainfall has not the same effect. The greater portion of the rainfall passes very quickly, and even if it does not pass quickly a great deal of it is collected in reservoirs and very large fresh water dams for manufacturers.

20527. You are not in favour therefore of varying standards according to the circumstances of different parts of a stream; you have told us why?—No, I am not.

20528. But I rather gather you are not in favour of fixed standards at all, are you?—I am not, sir.

20529. You have been good enough before to express to us an opinion in writing upon that; would it be possible for you now briefly to restate it?—I think, sir, that if you fix a standard you will have to fix that standard so that in no case where the effluent exceeds that standard would you get pollution of the stream. I think you would find that many effluents which exceed that standard would not cause pollution. In some cases you would get effluents containing more organic matter than the standard permits of, but owing to the volume of the stream or the rapid flow of the stream that such an effluent, although above the limit, would not cause pollution. I also think, sir, that the volume and nature of trade refuse, which is very, very variable in its constitution in the sewers, ought to be considered; also one town which contains in its sewage a great deal of fæcal matter and urinal matter, and another town which contains less fæcal matter owing to the different systems in use in those towns, would make it extremely difficult to fix a standard, the same standard for the two towns. Also, sir, I think that when you have in one town a separate system for the storm water, and, in another, the combined system where they take the whole of their water, the effect of these waters on the sewage is such that it would be very difficult to fix the standards to meet the two cases. I also think, sir, with all due deference, that we hardly know as yet how far sewage treatment is practicable.

20530. Your objection is rather to the fixing of a standard at present than to the fixing of a standard at all?—I am not in favour of a standard.

20531. As a fact, you work upon a sort of gradual standard now, do you not?—We do.

20532. So that you do find it useful and practicable to have that standard, although it may be absolutely a provisional one?—We do, sir.

20533. Should you think a standard ought to be based upon the non-putrescibility of an effluent undiluted?—To some extent, but an effluent may be putrescible under certain conditions, whereas the analysis, unless very complete, would not show putrescence. And also, sir, we have our streams containing a very large amount of manufacturers' effluent, the trade effluent may in itself not putresce, but it may have such an effect on the sewage effluent that you get the whole river putrescing.

20534. You mean that the standard should take into account that it is quite possible for an effluent to be non-putrescent by itself, but actually to bring about putrefaction when it is diluted with the volume of the stream?—I think it is quite possible.

20535. But is it not possible to cover that by making your standard such as, for instance, it should be based upon the amount of oxygen taken up at a given time?—I think, sir, the conditions in which it takes up the oxygen either alone or diluted are so very, very variable that if you fix your standard, in some cases your standard will say to you that this man is committing an offence when he really is not committing one, or *vice versa*.

20536. Dr. McGowan, would you like to ask Mr. Halliwell anything upon this point?

20537. (*Dr. McGowan.*) I did not quite follow an answer of Mr. Halliwell's just now; I might ask him to enlarge it a little. You said that you might have an effluent which was non-putrescible in itself, but that if it went into a stream it might cause putrescence in that stream; but then is that not because the stream water was a worse effluent than itself?—That is so.

20538. So that as a matter of fact you are talking of running an effluent which would be classed as non-putrescible into an effluent which would be classed as putrescible, but under the name of stream?—Yes, sir, it is a question as to whether you could make a sewage effluent standard applicable to a manufacturers' effluent standard.

20539. Had you any instance in mind when you made that answer about an effluent non-putrescible becoming putrescent when it goes into a stream?—I cannot put my hand upon a definite case; I believe it is the case in some of our streams.

20540. It is a most interesting point, and if you could give us some information on that point we should like to have it?—I am judging from these grounds, sir. I do not doubt the whole volume of some of our streams in summer is entirely manufacturers' effluent, plus some sewage effluent; below the point of the last receiving of sewage effluent there are several large weirs, now behind those weirs there is a nuisance; higher up the stream where the weirs are not present, you cannot complain of the condition of the stream.

20541. Then, I take it, probably the nuisance arises behind the weirs from the accumulation of solid matter?—That is so.

20542. So if your standard made provision as regards solid matter you would probably avoid that, would you not?—Well, sir, I have several cases in mind where an effluent itself is not putrescent. If you take the Accrington samples, which you will probably know of, the sample itself will not putresce, but if you allow the sample to settle for a little while, pour off the top water, add fresh water to the sediment which has settled out, that sediment will take up the dissolved oxygen from the water; and I take it it is the same thing that happens in the stream. Take the Accrington case; the nitrates present in the supernatant liquor are sufficient to prevent that liquor putrescing, but the suspended matter which, although small in the effluent itself, accumulates behind these weirs, and in the goits and the dams, the supernatant water is passed, and you get the sediment due to this accumulation of matter, putrescible, and setting up putrescence in the whole river. Now, we have several cases of that sort. Of course, on the other rivers, on the Ribble itself, which is a large stream and in good condition, I do not think that you would have anything like the same effect; I do not think it would be felt as the water passes away—it is not held up to any considerable extent—and we should not have the same nuisance. But take the Douglas, another of our main rivers. The whole volume of the river in dry weather is passed through a manufacturer's mill dam, and an opportunity given for any or all of the suspended matter to be deposited. Above this point there is a sewage works, and a very large volume of trade effluent, several million gallons, everything goes into the milldam, settles, and causes putrescence. It is on those lines which I think prevent you fixing the standard, because it depends on the local circumstances of the river, some distance below the point of the effluents which you are judging.

20543. There is just one more question, if I might ask you, Mr. Halliwell. You say that at present you do not think it would be advisable to fix a standard; you are not absolutely against a standard. Supposing you were in a position to fix a standard, have you formed any idea in your own mind as to the principles upon which you would base the standard?—Yes, sir. The first strict rule, to my mind, would be the removal of the suspended matter; I was going to say almost the entire removal of it. I think three parts per 100,000 would in some cases be not severe enough. It is the accumulation of it which I fear so much. After the removal of the suspended matter, I think one should judge of the rate and amount of dissolved oxygen which that effluent should take up; both the amount and the rate, not necessarily one, but both together. I also think, of

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course, that absorption depends more or less upon the nitrates present in your effluent. In sewage effluents, I think, you ought to have nitrates present to some extent, not necessarily a very large extent. Of course, some classes of effluents do not contain so much nitrate as other classes do, although the one containing less nitrate might be a better effluent than the one containing a large amount.

20544. What would be the object of having nitrate present in the standard?—If you have nitrate present it shows that nitrification to some extent has gone on; it has reached that point where further nitrification could go on.

20545. (*Chairman.*) The effect of dissolved oxygen in the effluent would be the same, would it not—that you would get oxygen there to complete the purification of the remaining organic matter?—Yes, sir, of course you would.

20546. So it is immaterial whether the oxygen exists in the form of nitrates or in the form simply of dissolved oxygen?—I say I should require more than that; I should want the effluent to contain dissolved oxygen in addition to the nitrate.

20547. The practical point you were putting before us, which interests us very much, is that you think the measure of the dissolved oxygen taken up by an effluent is a valuable test?—I do.

20548. And that that, in connection with the amount of suspended matter, might be a sufficient test?—I would not like to go so far as that, sir; those points I think ought to be considered.

20549. What points?—The amount of the dissolved oxygen, and the rate at which that dissolved oxygen is taken up or disappears, whichever way you like to take it; and the entire removal of the suspended matter. But at the same time I also think that the others ought to be considered—the other points, such as oxygen absorbed and nitrogeneous matter, should be considered.

20550. But suppose an effluent passed a reasonable standard in connection with dissolved oxygen, would you not be satisfied with it?—My difficulty, sir, would be to fix a standard for the dissolved oxygen. It should perpaps be on those fines, but personally I could not say what figures would satisfy our watershed.

20551. Well, let me put an example before you. Suppose you have an effluent, and you shake it up and you saturate it, and after 24 hours you still find it contains half its dissolved oxygen, would you consider that satisfactory?—After 24 hours?

20552. Yes?—Not in itself.

20553. You would think it necessary to investigate it further?—I do, and on these grounds—that some distance below where this effluent is discharged into the stream, the stream is used, or is probably used, by some manufacturer who increases the temperature very markedly of nearly the whole volume of the stream. Now if he does that you will probably find that he not only removes by increasing the temperature some of the dissolved oxygen, but he also tends to hasten any putrefaction which can occur. We feel in our watershed the usage of the water very severely. The temperature of the water of the rivers is distinctly high in many of our cases; it is so often used and re-used and used again by manufacturers either for condensing purposes or boiler purposes, or in some cases manufacturing purposes.

20554. Are we to gather that in your opinion, on account of the temperature of the streams in your district, you consider that an effluent which after 24 hours had not taken up more than half the dissolved oxygen, would still be objectionable?—I would rather put it this way, sir—that I am not sufficiently confident as to what would happen; I would rather not express an opinion. I think it is quite possible in some cases it would occur, but I cannot give you a definite case.

20555. Speaking generally, then, you would have confidence in a standard which was based upon the amount of oxygen taken up, and also upon a certain limitation of suspended matter?—I think these are the lines which should be considered.

20556. But you do not think it would be applicable in all cases?—No.

20557. With regard to zones, you think it is not desirable to divide into zones, but go much further and consider each specific case by itself?—Each specific case by itself.

20558. (*Major-General Carey.*) Do you modify your provisional standard according to the locality or position?—No, sir. The provisional standard is very useful in this respect, that in many of our works the committees and managers like to know how the results compare with other places, and they are interested in those results; they can understand a simple figure. But in some cases our provisional standard is affected by other things; I must admit in some cases the albuminoid ammonia standard is unsatisfactory; other figures would show it was satisfactory, and *vice versâ*. Those are considered by us before we take steps to compel further purification.

20559. (*Chairman.*) There remain one or two questions which I want to ask you on the important question of the treatment of storm waters. I suppose I may take it in your district not every local authority can be said at present to effectively treat even its dry weather flow?—Not every authority.

20560. Does any important authority in your district treat effectively not only its dry weather flow, but some dilutions beside?—They do.

20561. Tell us what you think is practicable to be done by local authorities so far as your experience goes. First tell us what you think it would be desirable to aim at doing in the direction of dilution, and then what you think it would be practicable to do—practicable, I mean, for financial reasons?—Certainly.

20562. First of all may I take it that you think many more than six volumes should be treated if you are to prevent the pollution of a stream?—I am afraid, sir, I hold rather different opinions in connection with storm water than I have ever seen expressed. I hold that at the beginning of a storm the whole of the waters should be treated whatever that volume happens to be at the time.

20563. It might rise, might it not, to a very large number of dilutions?—Yes, to a considerable number.

20564. Although you may think that theoretically it ought to be done, you are limited by such considerations as the area of the sewers, for instance?—Undoubtedly. The sewers will take at the beginning of a storm—in most cases that we have to deal with, ordinary sewers will take the first half-hour's rain at any rate, as a rule; it must be a very heavy rainfall that is not taken into the sewers. At the beginning of a storm the sewage is incomparably worse than the ordinary dry weather flow.

20565. Your view, then, is the same we have heard expressed in other directions—that the early dilutions of sewage are much worse than the dry weather flow was?—Undoubtedly.

20566. And even with six dilutions that is the case?—That is so. It depends largely, sir, upon several points, important points. Firstly, it depends on the incline of the sewers and the conditions of the sewers. There is one case in our watershed where at the beginning of a storm the overflow is extremely bad; in that case it is an oldish town, the sewers have been laid for many years, and have more or less sunk. The result is that you get with a little storm the washing out of these sewers, which causes a discharge of a very strong sewage. And I might draw your attention to samples which I took from one town. In this case the samples of the sewage were taken every day for a week; they were average samples, taken, I believe, every 10 minutes for a period of one hour. The analyses were as follows:—August 7th, the suspended matter was 8.

20567. Eight there means 8 parts per 100,000?—Eight parts per 100,000; the next day it was 24; on the next day there was a storm, and samples were taken of the overflow to the river every 10 minutes for 1½ hours; the suspended matter was 370. The next day the suspended matter was 26; the next day it was 18·5; the following day there was another storm, and the suspended matter increased to 178. Now, in that town, sir, the sewers are, comparatively speaking, old; it is a colliery district, and there has been a great deal of subsidence. The normal sewage, I believe, is weaker than in most towns owing to a lot of the suspended matter settling in the sewers; if you get a storm the sewers are washed out completely.

20568. When you tell us that the storm sewage was worse, and even many times worse, than the dry weather flow, you would probably find, would you not, that it was due to an excess of suspended matter rather than of dissolved impurities; have you investigated that

point?—That is so; it is more in connection with the suspended matter, but the suspended matters are largely organic matters.

20569. Should I be right in taking your opinion to be this—that in storm waters the main thing to do is to settle the suspended matter?—Yes.

20570. Have you tried any experiments yourself in regard to storm waters, of filtering such storm waters, and then estimating the amount of dissolved impurities?—I have taken samples, sir, of storm water in which the treatment has been simply settlement or precipitation.

20571. Well?—And in that case it is quite sufficient.

20572. You find that what is left after unassisted settlement of storm waters may safely be allowed to pass?—I think so, sir, undoubtedly. My opinion is that if you remove the suspended matter you can safely allow the other to go. Not only is that matter in solution less polluting, but the river is probably in flood at the time, and can take that matter in solution without causing any nuisance; but the suspended matter if allowed to go forward would settle in the river. Another important feature is the amount of trade refuse in the sewers. In one case a little while back we had a sample from a storm water overflow during a storm which was very much worse than usually is the case. On investigation we found that at this particular time there was an excessive quantity of trade refuse going into the sewer. In this case the manufacturer had an agreement with the Corporation to take the worst portions of his trade refuse.

20573. You say "too big"; do you mean to take into the sewers?—Yes; the manufacturer passes his trade refuse into tanks; the letting off of these tanks is in the hands of the local authority; they can let them off as they wish. The tanks were full, or nearly full; the man who had control of the tanks discharged the tanks into the sewers at the time when the sewers were charged with rain, the result was that most of the manufacturers' trade refuse went through the storm water overflow into the river. That may be an exceptional case, but it did happen. The authority, on this case being pointed out to them, said they would in future take more care.

20574. Even in your own district that was an exceptional case, was it?—I think so, but it may happen, and is very likely to happen; so that to my mind you must consider, on the question of storm water overflows, the amount of trade refuse, and the nature of the trade refuse, which is going into the sewers.

20575. But, speaking generally, we have got your opinion so far that storm waters are exceedingly impure, but their impurity is mainly due to suspended matter?—That is so.

20576. The settlement of such suspended matter, speaking generally and broadly, would be sufficient treatment?—That is so.

20577. The next point we want to get at is how many volumes is it practicable to ask authorities to deal with?—I have considered that point, sir, and I think the volume they should deal with depends on the distance of the sewage works from the town, and also the nature of the town. I might, for example, point out: We have in one case a town in which the sewage works are close to the town; it is a hilly district. At the beginning of the storm the rain passes quickly into the sewers and gets away; the sewers do not feel the effect of that storm for any length of time; but in other cases the sewage works may be some distance away, and the sewers having a slow gradient, the sewage does not get to the sewage works in the same time; and, therefore, if you have your storm water overflows made in several places you will take to your sewage works a very great deal less liquid than a town where the sewage works are close at hand.

20578. You think that whatever rule is adopted such rule cannot be applicable in all cases?—I think so, sir.

20579. Are you able to express an opinion upon the provisional rule, which has been laid down by the Local Government Board as a condition for sanctioning the loans, as to whether the six times, which are to be treated, partially and wholly, meet the case?—I do not think they meet the case.

20580. You think that more should be done?—I think there should be more latitude shown. If possible they ought to treat more than six times at the beginning of the storm, and afterwards, I think, it is quite feasible that less than six times should be treated.

20581. Then that would involve, would it, a storage?—It would involve a storage.

20582. You would not suggest that the works should be enlarged so as to deal with a larger number of volumes than six, even for short periods?—I think, sir, for a short period it is possible to deal with more than six, and that is done in our own watershed.

20583. In other words, you think it is possible to overwork the plant for a limited period?—I do. You have to treat say up to three times as normal sewage, and from three to six as storm water sewage. It is often argued in the district that if you can pass into the stream effluent from sewage which only needs partial treatment, that is to say, from the three to the six, you ought only to treat partially the one to six, and in some cases they do that; but they store the first portion of their sewage; then when the sewage is diluted they will only give it a partial treatment, but they will be treating fully the sewage which they have stored, which is the strongest portion.

20584. The mere storage involves very considerable outlay, does it not?—It depends very largely. In some cases they can afford to do it. In some of the normal plant they can reserve a tank or tanks for the first portion of the storm sewage, whatever strength that may be.

20585. Are the sewers as a rule capable of bringing down more than six volumes?—In some cases they are and in others they are not; in some cases they cannot take six times under any conditions; but as a rule the main storm overflow is at the works.

20586. So that you could not carry out your suggestion to advocate that not only six but more than six, except by duplicating the main sewers in those places?—The length of sewer which would need duplicating is very variable; they often have sufficient sewers, the sewers are sufficiently large to take over six times to a certain point, and the duplication of sewer might only mean in some cases, comparatively speaking, a small length.

20587. We may take it as your view that, speaking generally, the treatment of six volumes, some of them thoroughly and some of them partially, is a fair thing to ask the authority to do, but that you think in the beginnings of storms, even more should be done?—I do.

20588. Now, is it practicable to do that financially; have you in your district any authority that is dealing with six volumes of its dry weather flow?—We have several.

20589. Would you name some to us?—Brierfield are dealing with at least six times the dry weather flow.

20590. What is the population?—I believe the population is about 10,000.

20591. Are there many such authorities in your district?—Several are treating at least six times dry weather flow. Darwen is the case where they take the whole of it, whatever it happens to be.

20592. That the sewers bring down?—Yes; and the sewers bring far more than six times, and they deal with it for a time.

20593. In expressing to us an opinion that it is financially practicable for authorities to deal with six volumes, you are basing your opinion on the fact that that is actually done by certain authorities in your district?—That it is actually done by certain authorities.

20594. You told us in your earlier evidence that you thought it inadvisable to have fixed standards because they could not be applicable in all places, not even in zones, upon a stream, but that they must be considered in relation to the particular merits of each case on the river; therefore, after fixing the number of volumes to be treated, you must also be guided in each case by the local circumstances?—Undoubtedly.

20595. You do not think it practicable to lay down any general rule?—I think it is impossible, and one of my reasons for objecting to standards is the fact of the presence of storm water; the storm water question is one of the main features to my mind for objecting to standards.

20596. Would there not be very great difficulty with the Local Government Board or any supervising autho-

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rity in considering a scheme if they had not in their minds some sort of standard as to the amount of capacity that sewers should have?—Undoubtedly it is a difficulty, but I think it is less difficult to consider a place on its merits, and there is less likelihood of granting favours to one place and disfavours to another if you consider it on its merits rather than put down a fixed standard.

20597. Considering each case on its merits, what is to be the basis of your decision?—I think it would be quite possible that samples should be taken and the volume of liquid measured at frequent intervals. After considering the analyses and volumes you should be able to say when the storm water overflow should be allowed to come into operation.

20598. The quality of the storm water would be the basis of the decision that you would come to in each case?—No, not the quantity; I should take it on the nature of the overflow, not on the quantity—on the nature of it.

20599. What do you mean by the nature if not the quality?—I beg your pardon; I thought you said quantity.

20600. No, I said quality?—Quality—I should, sir. If I might mention one matter in the question of storm overflows, we have a case in point. There is an authority discharging from a storm water overflow which does not come into operation until more than six times dry weather flow is passing; but that overflow goes to a river which is impounded in its lower reaches by a manufacturer. The manufacturer complains to us that this stream is polluted. I do not think this particular overflow comes into operation until 10 times the dry weather flow is passing down. The authorities say, "If we treat six times, the Local Government Board say we are justified in passing into the stream," but undoubtedly the manufacturer has some reason for complaint. Here again it is a question of the stream into which the storm overflow discharges, and therefore not only must you consider the quality of your overflow, and the quantity of your overflow, but you must consider the river into which it overflows.

20601. Thank you, Mr. Halliwell; we are much obliged to you for coming to us and giving us the valuable evidence you have given us to-day.

Copy Letter from the Ribble Joint Committee.

(*Secretary.*)

Ribble Joint Committee.
County Offices, Preston,
8th December, 1904.

Sir,—I am directed by the Ribble Joint Committee to draw the attention of the Royal Commission to the question of amending the Rivers Pollution Prevention Act, 1876, in order that a certain class of offence which is causing the greatest possible harm to the rivers in this watershed may be more readily dealt with by local authorities entrusted with the carrying out of the Act than is possible as the law now stands. During the 13 years that the Joint Committee has been in existence a considerable amount of work has been done in getting manufacturers to put down purification plant, but occasionally some manufacturers are detected running off their precipitating tanks, and thereby allowing the deposited solids at the bottom of the tanks to be carried away to the river. A case in point is a well-known paper company who were compelled by the action of the Ribble Joint Committee to construct purification works at their two mills, and on the 10th March last during the night time the precipitating tanks at each mill were run off simultaneously into the river, the offence being detected by the Rivers Inspector. On the 14th March the Committee decided to take proceedings; on the 30th March an application was made to the Local Government Board for an order to do so; the Board held an inquiry on the 6th May, and gave their consent on the 30th June; this was reported to the Joint Committee on the 11th July; and on the 23rd September an action was heard at Darwen County Court when the firm were ordered to abstain from committing similar offences in the future, and to pay the costs. Upwards of six months elapsed from the date the offence was committed before the matter could be brought before the County Court. The order of the court did not require the firm to construct additional works, but simply to make proper use of those already existing.

The Committee are of opinion that it ought not to be necessary in a case of this kind to obtain the sanction of the Local Government Board before taking a case into the County Court to obtain an order compelling the manufacturers to refrain from making improper use of existing purification plant.

I enclose particulars of several other cases of a similar kind, showing that the practice of running off precipitating tanks surreptitiously is by no means an uncommon occurrence, and is one which is difficult to stamp out, as the law now stands.

The Committee beg to suggest that the law might usefully be amended in this direction, and further that the County Court should have power to inflict such a fine as the Judge might think proper, having regard to the circumstances of the case. At present the County Court cannot inflict a fine, except in a case where an order has been previously made by the court and disobeyed.—I am, Sir,

Your obedient Servant,
H. E. Clare,
Clerk to the Joint Committee.

Enclosures to Letter from Ribble Joint Committee.

Ribble Watershed Joint Committee.

At a meeting of the Joint Committee to enforce the provisions of the Rivers Pollution Prevention Act, 1876, in relation to parts of the River Ribble, held at the County Offices, in Preston, on Monday, the 12th day of September, 1904.

PRESENT:—

The Right Hon. Sir J. T. Hibbert, K.C.B. (Chairman), etc., etc.

Suggested Amendment to the Rivers Pollution Prevention Act, 1876.

Resolved.—That a recommendation be made to the Royal Commission on Sewage Disposal that in any further legislation relating to rivers pollution it should be made an offence, punishable by a fine, for any person to wilfully misuse works which have been constructed for dealing with the effluent proceeding from a manufactory or manufacturing process, and that in such a case it should not be necessary to obtain the consent of the Local Government Board before taking proceedings.

H. E. Clare,
Clerk to the Joint Committee.

Royal Commission on Sewage Disposal.

MAP HANDED IN BY MR E. HALLIWELL.

RIBBLE JOINT COMMITTEE.

MAP OF WATERSHED.

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EXPLANATION.

Discharge from Sewage Works .....

do. do. Sewage Crude .....

do. do. Print, Dye & Bleach Works .....

do. do. Paper Works .....

do. do. Chemical Works .....

do. do. Tanneries & Fell Mongers .....

do. do. Breweries .....

Note. All figures are normal dry weather flow in gallons per 24 hours.

[The Blue shading in the rivers marks their tidal limits.]

EDWARD HALLIWELL F.I.C.
Chief Inspector,
PRESTON.

5236.

Weller & Graham, Ltd Litho. London

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Plant. Business—Calico Printers.

		Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours.
1902.				
September 13th	Crude Liquor to Tanks.	212·0	272·0	—
1903.				
March 20th	Crude Liquor to Tanks.	96·0	171·0	—
October 1st	Final Effluent	4·4	42·0	—
November 12th	do.	7·2	83·0	—
1904.				
June 2nd	do.	4·8	57·0	—
June 22nd	do.	7·4	77·0	—
July 22nd	do.	6·0	48·0	—
September 20th	do.	5·2	55·0	—
January 8th	Sample of discharge of sludge owing to improper use of works or negligence.	1074·0	406·0	126·1

EDWARD HALLIWELL, F.I.C.

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Plant. Business—Brown Paper Works.

		Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours' test.
1903.				
January 14th	Crude Liquor to Tanks.	290·0	477·0	39·6
1902				
October 7th	Final Effluent.	9·0	250·6	—
1903.				
January 14th	do.	5·0	304·0	18·1
February 20th	do.	14·2	321·0	21·3
July 8th	do.	6·0	280·0	—
1904.				
August 22nd	Sample of discharge of sludge owing to improper use of works or negligence.	686·0	96·0	102·0

EDWARD HALLIWELL, F.I.C.

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Plant. Business—Dye Works.

		Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours' test.
1902.				
September 22nd	Final Effluent.	5·8	76·0	—
October 23rd	do.	7·0	84·0	—
1903.				
April 21st	do.	4·0	122·0	—
October 8th	do.	6·4	111·0	—
1904:				
February 2nd	do.	6·6	89·0	
October 3rd	do.	3·0	134·0	—
August 8th	Sample of discharge of sludge owing to improper use of works or negligence.	114·0	119·0	20·0

EDWARD HALLIWELL, F.I.C.

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Plant. Business—Printers' Dyers.

		Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours.
1902,				
August 27th	Final Effluent.	8·0	91·0	—
November 11th	do.	1·8	113·0	—
December 10th	do.	2·8	92·0	—
1904.				
January 6th	do.	4·4	89·0	—
July 26th	do.	5·6	99·0	—
September 21st	do.	8·0	116·0	—
October 17th	Sample of discharge of sludge owing to improper use of works or negligence.	1836·0	212·0	92·0

EDWARD HALLIWELL, F.I.C.

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Plant. Business—Dyers.

		Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours' test.
1902.				
October 23rd	Final Effluent.	·5	120·0	—
November 6th	do.	2·8	265·0	228·0
1903.				
February 5th	do.	1·6	264·0	—
June 4th	do.	6.4	188·0	—
1904.				
January 28th	do.	1·8	306·0	—
May 19th	do.	15·4	196·0	—
September 22nd	Sample of discharge of sludge owing to improper use of works or negligence.	2564·0	720·0	640·0

EDWARD HALLIWELL, F.I.C.

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Plant. Business—Brown Paper Works.

		Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours' test.
1903.				
January 9th	Crude Liquor to Tanks.	59·0	71·0	10·9
January 9th	do.	11·0	63·0	5·0
June 29th	Final Effluent.	6·8	60·0	—
September 24th	do.	6·8	76·0	—
October 20th	do.	8·2	51·0	—
December 1st	do.	10·6	79·0	—
1904.				
January 22nd	do.	11·8	72·0	—
March 22nd	do.	8·0	76·0	
March 9th	do.	16·0	81·0	8·08
March 10th	do.	13·3	75·0	7·92
March 10th	Sample of discharge of sludge owing to improper use of works or negligence.	1612·0	112·0	143·7

RIBBLE JOINT COMMITTEE.

Samples taken at Purification Works. Business—White Paper Works.

——	——	Parts per 100,000.		
		Suspended Solids.	Dissolved Solids.	Oxygen absorbed in 4 hours' test.
1903				
January 5th	Crude Liquor to Tanks.	204·0	54·0	—
July 8th	Final Effluent.	2·0	46·0	—
September 24th	do.	1·0	47·0	—
October 20th	do.	·6	44·0	—
December 1st	do.	2·2	61·0	—
1904.				
January 22nd	do.	1·2	56·0	—
March 22nd	do.	1·4	48·0	—
1904.				
March 9th	Samples of river water taken below mill.	6·5	29·0	0·71
March 10th	do.	2·0	23·5	0·21
March 11th	do. Owing to improper use of works or negligence.	1094·0	41·0	107·6

EDWARD HALLIWELL, F.I.C.

DR. GEORGE REID, called in; and Examined.

Dr. George Reid.

9 Dec. 1904.

20602. *(Chairman.)* You are medical officer of health of the Staffordshire County Council?—Yes, sir, I am.

20603. And in that capacity you have had very considerable experience of sewage treatment and sewage works, and we should be very pleased to have your opinion to-day upon certain specific matters. You are, I understand, to give us some evidence on the other matters at a later date. First, in regard to your experience as to the best tests for sewage effluents, would you be good enough to say what tests you use yourself and how far you find them reliable?—I use the free and albuminoid ammonia tests, the oxygen absorbed in four hours at 80° F., the nitrate nitrogen, and I always estimate the solids in suspension and in solution, and the chlorine; also, we have in Staffordshire a standard of opacity which is one I introduced some ten years ago. The standard is a disc at the bottom of a 2-foot cube with certain lines, fine cross lines. The tube is graduated into half inches, so that we are then able to put down a certain figure representing the opacity of the effluent for what it is worth. I believe that the same standard has been adopted in several other counties since we started it in Stafford. I intended to have brought this particular disc with me to have shown it, but I have forgotten to.

20604. Do you find the test as to opacity of great value?—Well, it is not of great value, but it is useful when you come to look at the figures some years hence, as it may throw some light on some rather extraordinary results. You may then by this opacity test be able to say, "Oh! but it was a horribly filthy-looking stuff."

20605. An effluent might analyse very well, but where there was an opalescence it probably would tell against it?—It would in that case, and to that extent I would discard it. There are certain works, for example, that we get our regular clear effluents from, and if suddenly those works should begin to show an opaque effluent figure I should think there would be something wrong, simply from that fact only, apart from the other figures, and probably it would be accounted for by something happening in the management that was wrong. It is not an important thing at all, but there it is; it is not easy to describe the appearance of an effluent, and it obviates the necessity for describing it if you are able simply to use a figure.

20606. Have you found your oxygen absorbed and albuminoid ammonia test to be generally sufficient and reliable?—I think so.

20607. Do you pay much attention to the incubator test?—No, I have not done so. The reason for that is that in Staffordshire effluents are either bad or good; that is the position at present. The modern works in Staffordshire are practically all good works, and it would be needless to go through the incubator test, because the effluents, on the face of it, could not putrefy—the amount of nitrates in them compared with the amount of organic nitrogen is such that they could not putrefy.

20608. Have you used to any extent or at all the dissolved oxygen test?—No, not at all.

20609. Should you consider that that test by itself might be sufficient for a good effluent?—I am afraid I should not like to say that it would be.

20610. It is a matter to which you have not given any personal attention?—No, I have not.

20611. I am very sorry that my colleague Sir William Ramsay is not here to-day; probably he might have been glad on these technical points of the oppor-

tunity of putting some questions; in his absence I would ask Dr. McGowan if he would like to ask any questions bearing on this question of tests.

20612. (*Dr. McGowan.*) I do not think I have much to add to what you have just said. In the summary of evidence, which you sent in, you say: "In judging of the quality of an effluent, various analytical figures have to be taken into account, and, as the significance of each is governed by the others, it would not be feasible to fix a definite individual minimum." Here is the point I wanted to ask you about: "Moreover, it would be misleading and erroneous to base a standard upon one figure, because the limit within which that figure might vary in a good effluent is considerable, taking other figures into account"?—Yes.

20613. I do not quite follow that sentence; it is a crucial sentence, and I do not quite gather what your view is?—This is the point. Supposing you have a certain quantity of organic ammonia, say 0·08 of organic ammonia and a very small nitrate nitrogen figure, it is quite possible that that would be a polluting effluent. On the other hand, you might have a larger amount than 0·1 of organic ammonia, and with that a high nitrate nitrogen figure, in which case it might not be a polluting effluent. That is my point with regard to that; that is to say, you have a certain amount of available oxygen in your effluent to be liberated and to carry on the work after the treatment is over, and that is, I think, one great difficulty in arriving at one figure as a basis for a standard.

20614. (*Chairman.*) In any case what you are aiming at is to ascertain the putrescibility or otherwise of an effluent?—That is so.

20615. (*Dr McGowan.*) But you have given no attention whatever to the rate at which an effluent takes up dissolved oxygen?—No, I have not, except I have formed a sort of impression, which impression has varied from time to time. I have never gone into the matter for the purpose of ascertaining that, but sometimes when samples have lain for some time in the laboratory I have come to the conclusion that they had lost nitrates, as they had been very much better when analysed sooner; I have never done anything systematically in order to arrive at an answer to that question.

20616. (*Chairman.*) The next point I would like to ask your opinion upon is the desirability of having standards at all for sewage effluent, and if you have a standard, how far it would be desirable to modify it according to the circumstances of streams in certain zones?—Yes; well, I think that it would be desirable if possible to have a standard; it would be a most convenient thing to be able simply to say: "You are not up to the standard, therefore you must do something more." But the difficulty of arriving at a standard is so great in my opinion that I do not think it is practicable to have an uniform standard. On the other hand, if some convenient method of arriving at a standard can chemically be laid down, and an accurate method devised, then I think it would be desirable to have a standard. But it should be made applicable to certain zones, as you say, and not to the country as a whole, because of the varying character of the districts, from the point of view of storm water, and the volume of the streams into which the effluents are to be discharged.

20617. Is there not another important point, namely, whether the waters of that stream are used for drinking purposes or not; ought not that to be taken into account?—Well, I am afraid I do not agree with that suggestion, because I do not think that any sewage disposal authority could, by any known method, at any rate, discharge an effluent which would be taken as satisfactory from the point of view of drinking water; and therefore it must involve further treatment of the water, and by laying down a standard from that point of view you would be asking the authority to deal with an enormous volume of fluid after it had been chemically purified—an enormous volume of fluid, one-sixth part of which, we will say, would have to be dealt with again from the point of view of drinking water by the drinking water authority lower down. It seems to me that the two authorities would in that case be doing the work seven times over, and when it was done you still have to consider the surplus storm water, which, I take it, you could not possibly deal with in that way.

20618. I gather when you speak of the standard being itself desirable it would be a chemical and not a bacteriological standard?—Quite so.

20619. You would not consider it necessary, therefore, that even where sewage effluents are passing into streams that are used for water supply, authorities should be called upon, to any extent, to sterilise such effluents?—Certainly not.

20620. You think that the work of eliminating organisms should be the work of the water-supplying authorities and not of the sewage-disposal authorities?—That is so; they have a much smaller quantity to handle to begin with, very much smaller.

20621. (*Major-Gen. Carey.*) What is your objection to sterilizing the effluent?—Well, first of all, I think that the cost would be enormous, of many methods that we know at present, the cost would be enormous; secondly, I do not think it would be practicable to sterilise all the discharges from the sewers, and unless you sterilise all the discharges from the sewers you would be misleading the public to some extent, that is to say, there would be a danger of a false security being established which might be dangerous at times. If you are going to establish a system of sterilisation you must sterilise everything you discharge from your sewers; if you do not do that, then the danger is very considerable.

20622. When you say everything you mean storm water in addition to sewage?—Yes. And apart from that, of course I do not know what form of sterilisation the Commission may have in view, but if it should be anything other than a mechanical sterilisation you would injure the stream in a sense, because you would not have the benefit of the purification which goes on afterwards if you turn a highly chemically purified effluent in; you get a great deal of the work done in the stream itself, but if you impose a certain condition with regard to sterilisation by certain methods you would then be turning in an inert fluid, in place of an active fluid with oxygen to do the work afterwards.

20623. By mechanical sterilisation I take it you mean very fine filtration?—Yes.

20624. (*Dr. Houston.*) As regards that last point sterilisation might actually improve the effluent from the point of view of purification. The last point that you raised was that you were frightened that if sterilisation were adopted the liquid going in would not be so pure?—Yes.

20625. But it probably would be purer if you used ozone or sodium hypochloride?—Yes.

20626. The liquid going in would be absolutely purer?—Except to this extent, you destroy the nitrifying organisms.

20627. That is a point that has to be considered, but, of course, those would be present in the river?—Yes.

20628. In some cases in rivers the waterworks authorities actually shut down the intake for waterworks purposes during a storm, so that it might not be absolutely necessary to sterilise all the storm water?—Yes.

20629. That is the case, I believe, on the Thames with some of the waterworks authorities; they close the intake during storms?—Yes.

20630. At least they say they do?—Yes.

20631. Then as regards cost? Would you consider £1 per million gallons prohibitive; that is as an adjunct to the rest of the treatment? You speak in your statement as if the Commission thought of sterilising raw sewage; I do not think the Commission have really considered the possibility of sterilising sewage; it would be always an adjunct if it was thought of at all?—Yes, quite so.

20632. So I do not think it need be considered except as an adjunct. Would you consider £1 per million gallons prohibitive?—I should say certainly. To what extent would you go in regard to dilution of storm water—to six times?

20633. Well, of course that raises another point, and a very difficult point, I admit.—Yes. The case depends largely upon that.

20634. As regards that storm water, you say the intended benefit would only be intermittently operative; but it is rather the other way round, the storm water would only be occasional; I mean it is hardly

Dr. George Reid.

9 Dec. 1904.

fair to put it that way?—Well, I did not mean to put it unfairly.

20635. Oh, I quite realise that. Of course the storm water is a very serious question?—If it cost £1 per million gallons it would cost Birmingham £130 a day.

20636. But there again is Birmingham a likely instance; in cases like that would sterilisation be likely to be necessary? It is more in cases, we will say, like the Thames or the Lee?—Yes.

20637. Where the last sewage works are just above the intakes of the waterworks company. If you sterilised there you would have a decided advantage, would you not, or might have?—Well, I do not quite know that you would have, because the water company could not by any possibility take that water to distribute it without further treatment.

20638. Well, there would be double security, would there not?—And if you have to treat it at all I do not see that you gain much by reducing the organisms beforehand. Surely a water filter, if it is effective, will take out a sufficient quantity, and it does not matter whether the number of organisms in that quantity is very great or very little, as long as they have to take them out.

20639. Yes, but then I fancy you would hold that filtration is only a relative safeguard; it is not an absolute safeguard?—Quite so.

20640. Whereas sterilisation is an absolute safeguard?—Yes; sterilisation is an absolute safeguard.

20641. In some cases there might be an economic advantage in sterilising the effluent and not the water, might there not? Suppose you have a waterworks that do not filter; they do not find it necessary to filter their water; it is a pure river, a pure stream, and there is a small town just above the intake discharging an effluent into it. Surely in such a case it might be an economical advantage to sterilise the effluent and not the water?—Then I think I would call upon the water authority to do it.

20642. That involves another question?—It does involve another question, but I think from the point of responsibility the water authority should do it.

20643. But on that very point the Commission have more power, have they not, as regards sewage disposal than as regards water?—Yes.

20644. I mean they have not received much evidence from waterworks officials?—No.

20645. And it is not so distinctly under the terms of their reference as the disposal of sewage?—No.

20646. And they could bring pressure to bear in certain cases on sewage disposal when they may not as regards water supplies—they cannot set up a code of ethics for waterworks authorities; that is a difficulty, is it not?—But the Commission might say this: Suppose the Commission come to the conclusion that in certain cases it is desirable to sterilise, they might express the opinion that in the opinion of the Commission it is the water authorities' duty, and not the sewage disposal authorities' duty, to do it. Otherwise, by reason of the accident of having lower down stream an authority taking water from that stream, you would be imposing a large expenditure on a sewage disposal authority, not because of any fault of theirs, but simply because they used the natural outlet for their effluents and the accidental circumstance comes in that there is a water company down below; so it is the water company in all cases who should do the work, not only from the point of view of payment, but from the point of view of having the responsibility placed upon them, because I do not think it would be right that the public should be at the mercy of a sewage disposal authority for the water that they drink; the water authority alone should be held responsible.

20647. (*Chairman.*) Then, proceeding, Dr. Reid, we would like very much to hear your opinion as to the extent to which storm waters should and can practically be treated?—Well, I do not think that the requirements of the Local Government Board are excessive in that respect; I think they are reasonable, in fact. I do not think an authority ought to be expected to go beyond that quantity. At the same time, there are local conditions which make it desirable to have provisos. For example, although six times the dry weather flow spread out over the 24 hours may be the amount, the works in certain cases should be so arranged that the first flush of a storm may not go into a stream even when that amount of dilution is reached. This involves the question of storage, and I think that in some cases it is desirable to have storage tanks for the first flush from the sewers; that is to say, even if it should be considerably beyond six times the dry weather flow for a certain period, and that after that period what comes down may go into the river, while the other is held back for treatment at the leisure of the authority.

20648. Would not that storage be rather a serious business; how many hours' flow would you suggest should be stored?—Well, it would not be many hours; it would be a comparatively small period in most cases. It is the first flush that comes from the sewer, particularly after a dry period, which is very foul, and if the sewers are on a steep gradient—I have a case in mind at the present moment in North Staffordshire, of a district called Tunstall—I do not know whether the Commissioners happen to know that district—but if you stand on the works and a little rain happens to come, an ordinary shower of rain, in the course of half an hour the overflow at the works is discharging straight into the stream and discharging very offensive sewage. Then, in a very short time, comparatively, the quality of that sewage improves very much, so that then it might go into the stream. They ought not to be allowed to turn anything over under six times the dry weather flow; but they ought to have the power of allowing more than that to go into a special tank. Of course, it is very difficult to say what storage should be provided—most difficult; so long as a tank is available and always empty it would be something gained, and the size might be regulated by local circumstances. Under the circumstances, I do not think you could lay down a strict rule with regard to the tank capacity; but you could, considering the contour of the district, and so on, probably arrive at a reasonable size for this tank, and granting that it is kept empty during dry weather and available for storm water, then when it is full the rest can go direct to stream after six times dilution. I think that is the only way by which you could arrive at a figure with regard to the volume to be so dealt with.

20649. As to the composition of storm waters, have you given that matter any attention?—No, I have not; not as to what extent it is affected by solids in suspension.

20650. Evidently the effect of the rain would not have increased the production of domestic sewage or trade effluents?—No; but it flushes down a large amount of deposit from the sewers of a very foul character.

20651. So that the foul condition of sewers, the accumulation in the sewers themselves, the gullies, and the washing down of roads, roofs, and so on?—Yes.

20652. And would be mainly suspended matter?—Yes; probably it is mainly that.

20653. Have you formed any opinion as to the sufficiency of settling suspended matters in storm waters? No; I have not.

20654. It might be interesting, if you are able to make any observations in your district, by separating out the suspended matters by filtration through paper and gauging the amount of dissolved impurities?—Yes; I could very easily do that.

20655. It would be interesting?—Except that one does not multiply those things: but I should be very pleased to do that. With regard to forming an opinion as to the capacity, one can judge very fairly of what happens in a detritus tank. In some cases you have a detritus tank upon a larger capacity per volume of sewage than in others, and you get a very large amount of suspended matter held back by the detritus tank. To duplicate the detritus tank and increase its size considerably would be a very fair safeguard in a case of sudden storms, because you would get a large amount of solids which go into the stream now in a tank even of that size, though, of course, it would have to be very much larger to be of any real service. It need not be anything like a day's flow, for example. You would get from a comparatively small tank very good results, in my opinion, from the point of view of the stream.

20656. Then you do not think, do you, that it is preferable to call upon local authorities to deal with more than six volumes; but you think it is practicable to call upon them to deal with six?—Yes; I think so, spread over the twenty-four hours. And then, of course, you would have to have conditions with regard to short

periods of more than that being held back in certain districts for subsequent treatment.

20657. How do you mean spread over twenty-four hours?—That is to say, the mean daily flow.

20658. You would require that their sewers should be capable of bringiug six times the average dry weather flow to the works?—Yes; to the works.

20659. And that such volumes should be dealt with at the works; possibly not in the same way as the dry weather flow, but should be dealt with, at all events, to the extent of settling suspended matter?—Yes,

20660. In other words, you think that by this provisional requirement the Local Government Board have just?—Happened to hit off the quantity.

20661. Hit off what is practicable?—I think so.

20662. If not, what is wholly desirable?—I think so.

20663. Does any authority in your district in fact do this?—I shall just have to think for a moment. Oh, yes, we have several authorities doing that, but most of the authorities who do that now have artificial means of disposal up to three times, and then they have land for discharging the storm sewage on to, and where land is available I think that is a very excellent way of dealing with it.

20664. Then, however, it is dealt with; certain authorities in your district do in fact deal with six times?—Yes.

20665. And you gather, therefore, that it is practicable to deal with it?—Now, for instance, at the Birmingham works; what they are endeavouring to arrive at is artificial filters for the dry weather flow, retaining some 1,400 acres of land practically almost for storm water only.

20666. What is proposed at Hanley in regard to storm water?—They propose to have some storm filters at Hanley.

20667. But I mean as regards the volume to be dealt with?—They have nine acres.

20668. How many volumes of the dry water flow?—Six times; it is the same as the Local Government Board requires.

20669. Judging from that and what has been done by other authorities, you give us your opinion that it is practicable for authorities to do this?—Authorities can do this at a cost of about £1 to 25s. per head of the population for works; that is what I think is about the average price.

20670. Is there any point in connection with storm waters that you would like to mention to us upon which I have not asked you questions?—I should like to call your attention to the figures; in the table I have given you, "Rainfall as affecting the condition of certain streams in Staffordshire," they are of different character. For instance, the Fowlea brook is a stream which is of small volume, you will notice, and on that stream there is a very large population. Now the result of storm water in that case, from these figures, appears to be that it never reaches the stage at which dilution begins to purify again. If you notice taking the organic ammonia figure ·13 when the rain is under one-tenth inch; 1·5 when it is over one-tenth and under one-fourth inch; 2 when it is over one-fourth—the day before, that is. (The table referred to is printed at the end of Dr. Reid's evidence.)

20671. That does not mean that when the rainfall is in quantity, but the stream is very much larger in quantity than when there was only one-tenth?—Oh, yes, it means that very much so; it is not only larger in quantity, but the stream is very much larger in volume, so the amount of impurity which is added to that stream is enormous.

20672. I see; this is not a gauging of effluent from works, but the condition of the stream itself?—The condition of the stream itself.

20673. And that is so throughout the table?—That is so throughout the table, yes. That is with regard to Fowlea brook. Then if you take the Lyme brook. The Lyme brook is a comparatively small stream, but it rises in a rural district, and there is a considerable rural as well as urban area draining to it, the result of that is that you get the impurity increased up to the quarter inch, but it begins to right itself again when you exceed the quarter inch. That is owing to surface, comparatively pure water going in. Now then take the Trent at Hanford, which may be said to be the sum of the other two streams practically plus the Trent. It is a small stream at that point, and the same thing takes place there again. After Hanley and all the big towns have gone in you get an impurity in the stream when the rainfall is under one-tenth of an inch—·09, it rises to 0·17, with quarter of an inch, and then begins to fall again when the dilution exceeds the quarter inch. But take the Tame at Tamworth, which is about the worst instance of pollution, I think, that you could have in the country. Here the volume of the stream and the volume of the sewage entering it are about equal, and we have an impurity figure of 0·1 with under one-tenth of an inch rainfall, and the same up to one-quarter inch. As, however, the rain records in this case are not very numerous we must not draw too hard and fast conclusions from them, but if you notice the next figure, 0·19, there is a very great increase, and that is 20 miles below the outfall.

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20674. That means that a great deal of untreated sewage passes by the storm overflows to the stream?—Yes. Then this stream has been diluted by other feeding streams going into it, so if we take the same streams higher up in the supplementary table below, that is immediately below the Birmingham works, immediately below where the sewage of nearly one million people goes into it, the impurity figure there when the rainfall is under one-fourth 0·18, and it rises up to 0·32, a most horrible condition of things, worse than many sewages when the storm overflows come into play. On the other hand, the Churnet is a pure stream, comparatively, and the normal conditions there are 0·019 organic ammonia, and by inflow from agricultural land the figure is raised to 0·03, and it appears to be maintained at 0·03, no matter how much the rainfall increases, so that you might look upon that as the normal increase of impurity from agricultural land in an ordinary district.

20675. And the table goes to show that it is in the abstract very desirable to treat as much storm water as possible?—Yes; and I think in the case of Birmingham the reason for this enormous impurity is the character of the sewers. They are old sewers; they are largely sewers of deposit, and are practically cesspools being periodically emptied, when the rainfall comes, and the remedy, of course, for that is very largely resewering Birmingham But after that they will have to come to a determination as to how much storm water they will deal with. There are many other points in connection with these figures, and there are other points taking further figures than the organic ammonia, but as it was I took three full days to work out these figures with two clerks at work upon them from my records. I could not therefore give any further figure than the organic ammonia, but all the figures are available. In these records—not only these but thousands of others—the full analysis has been made; they are all recorded and available for any inquiry the Commission may make.

20676. No doubt the organic ammonia would be a very good measure of the impurity of the stream?—The best single measure.

20677. We are very much obliged to you for coming over to give your most valuable evidence?—May I just mention there is a question with regard to the presence of weirs on streams. It has a very important bearing upon the question of storm water. In flat districts, and very often throughout Staffordshire, there are weirs—old weirs—and the result of that is that the rivers, flat in any case, are back pounded, and we get an enormous collection of sludge forming behind the weirs. The result, of course, of that is that when a little rainfall comes it is all washed down—not all, but a large portion is washed down, and of course the scouring capacity of the streams are diminished. Now, no central authority has power at the present moment to remove weirs from streams. Local authorities can get the power, but then if they do so, they are benefiting an area outside their own area in many cases, so that I think there ought to be some central authority who should have the power of purchasing mill rights for the purpose of abolishing weirs. We have had several abolished already with very excellent results, and such powers would get over a considerable difficulty in our county where the streams are so very small. The Trent rises in Staffordshire by mere trickles, and immediately it forms a little bit of a stream all these vast populations turn their sewage into it, so that we have a very difficult problem in

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Staffordshire, and it is complicated by the existence of a great many weirs.

20678. Then you have, in fact, many derelict weirs?—Yes; well, we have not many, but we have several, and they are on the main streams; consequently, the position is serious.

20679. (*Secretary.*) When you say the central authority should have power to buy them you mean the county authority?—The county authority.

20680. Not a Government authority?—No, the county authority, with power to rate the area benefited.

20681-2. A Rivers Board, if there was one, or a County Council, if there was not one.—To rate the authorities whose districts are to benefit by this.

20683. (*Dr. Houston.*) I have been reading this table with great interest. I gather that, as a rule, the water during storms in these rivers is more impure per unit of volume, although it is of much greater volume?—Yes.

20684. Have you formed any idea how you could set the one against the other, the increase of total volume against the increase of impurity per unit of volume, so far as contaminating liquids going in are concerned? You see what I mean, do you not?—That is to say, to gauge the quantity going in.

20685. Yes, because it is commonly asserted that during the flood time it is quite proper to discharge impure effluents into streams?—Yes.

20686. I do not think we have had much evidence on that point?—I have done that in connection with an inquiry in my district, and I had all the streams gauged for a certain number of months; accurately gauged by fixed weirs, as nearly accurate as possible; and having got a record of the actual flow of each tributary then I was able to attach the responsibility for impurity to certain localities. That is to say, the impurity figure of a certain stream would be a very high one, but the flow of that stream was a very low one. On the other hand, another stream coming in, the impurity figure might be a lower one, but the volume of flow was considerably higher. Therefore, the injury was greater; so, taking all these from the top points, and then taking the lower figure when they have all gone in, I have built up a table—at least, a diagram—showing the actual building up of the total impurity at the bottom, based upon the figures that you have just mentioned. I think that is what you mean, is it not?

20687. Yes; quite?—I have done that with regard to practically the whole of South Staffordshire. That was practically after an inquiry of two years' duration, and in consequence of the evidence certain authorities have spent some £500,000 in works, and are going to spend about the same sum more, I think.

20688. Might I venture to ask you to ask Dr. Reid if he could let us have these figures; they are very interesting.

20689. (*Chairman.*) Would it be possible for you to give us those?—Well, there are reasons, which the Commission will appreciate, for not making the records public, but no doubt I could collate them in a manner which would answer the purpose, without going into detail, regarding the authorities interested, and I shall be pleased to do so.

TABLE handed in by Dr. REID.

RAINFALL AS AFFECTING THE CONDITION OF certain STREAMS IN STAFFORDSHIRE.

	FOWLEA BROOK.			LYME BROOK AT HANFORD.			TRENT AT HANFORD.			TAME AT TAMWORTH.			CHURNET AT ROCESTER.		
	Rainfall day before.			Rainfall day before.			Rainfall day before.			Rainfall day before.			Rainfall day before.		
	Under $\frac{1}{10}$ in.	$\frac{1}{10}$ in. and under $\frac{1}{4}$ in.	$\frac{1}{4}$ in. and over.	Under $\frac{1}{10}$ in.	$\frac{1}{10}$ in. and under $\frac{1}{4}$ in.	$\frac{1}{4}$ in. and over.	Under $\frac{1}{10}$ in.	$\frac{1}{10}$ in. and under $\frac{1}{4}$ in.	$\frac{1}{4}$ in. and over.	Under $\frac{1}{10}$ in.	$\frac{1}{10}$ in. and under $\frac{1}{4}$ in.	$\frac{1}{4}$ in. and over.	Under $\frac{1}{10}$ in.	$\frac{1}{10}$ in. and under $\frac{1}{4}$ in.	$\frac{1}{4}$ in. and over.
No. of Records	39	10	9	41	7	10	39	11	8	38	7	7	36	10	6
Mean Rainfall. Day before	0·01in.	0·18in.	0·46in.	0·01in.	0·19in.	0·44in.	0·01in.	0·18in.	0·46in.	0·007in.	0·15in.	0·56in.	0·008in.	0·15in.	0·43in.
Mean Rainfall. Week before	0·43in.	0·73in.	1·10in.	0·49in.	0·69in.	1·03in.	0·43in.	0·86in.	1·15in.	0·38in.	0·69in.	1·13in.	0·45in.	0·83in.	1·04in.
Mean Rainfall. Month before	2·24in.	2·42in.	3·39in.	2·33in.	1·78in.	3·49in.	2·29in.	2·37in.	3·43in.	1·87in.	2·34in.	2·65in.	2·65in.	2·88in.	2·46in.
Organic Ammonia (parts per 100,000)	0·136	0·158	0·202	0·088	0·114	0·080	0·097	0·171	0·100	0·111	0·106	0·199	0 019	0·030	0·131
Flow in cubic feet per sec.	7·1	9·0	29·0	11·7	13·6	18·2	58	79	129	316	344	665	88	107	137

* These records are not comparative with those of the stream at Tamworth. The samples were specially collected throughout the period between February, 1896, and July, 1897.

TAME 20 MILES HIGHER UP (below Birmingham)*	
Total Rainfall 3 preceding days.	
Under $\frac{1}{4}$in.	Over $\frac{1}{4}$in.
No. of Records	10	9
Mean Rainfall	0·06	0·49
Organic Ammonia (parts per 100,000)	0·185	0·323

SEVENTY-SECOND DAY.

Tuesday, May 9th, 1905.

PRESENT:

The Right Honourable Earl of Iddesleigh (*Chairman*) presiding.
Major-General Constantine Phipps Carey, C.B., R.E.
Colonel T. W. Harding, J.P., D.L.
Sir William Ramsay, K.C.B., F.R.S.
Mr. W. H. Power, C.B., F.R.S.
Mr. T. J. Stafford, F.R.C.S.I.
and Mr. F. J. Willis (*Secretary*).

ALSO PRESENT:

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. G. H Pickles, A.M.I.C.E., Borough Engineer of Burnley, and Mr. Raymond Ross, F.I.C., F.C.S. Public Analyst, called in; and Examined.

Mr. G. H. Pickles, A.M.I.C.E., and Mr. Raymond Ross, F.I.C., F.C.S.

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20690. (*Chairman.*) You are Mr. Pickles, Associate Member of the Institute of Civil Engineers and Borough Engineer of Burnley?—(*Mr. Pickles.*) Yes.

20691. And you are Mr. Raymond Ross, Fellow of the Institute of Chemistry, and Fellow of the Chemical Society, and Public Analyst of Burnley?—(*Mr. Ross.*) Yes.

20692. The evidence which is to be given by both of you relates more particularly to your experience in the treatment of sewage at the Burnley Corporation sewage works?—Yes.

20693. What is the population draining to the Burnley works?—There are two outfalls, one for the Wood End and Duck-Pits area, the other for the Altham area. Our evidence is with regard to the Wood End and Duck-Pits works. The total population draining to these works is 82,000.

20694. What is the system of drainage, that is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent?—The area of the watershed is 2,800 acres, of which 1,012 acres are built upon. Of these 1,012 acres, 544 are sewered, the storm water being discharged into the sewer. The remaining 468 acres are provided with a system of surface water drainage in addition to the sewers.

20695. Is there any infiltration of subsoil water into the sewers?—Practically none.

20696. What is the water supply per head, and from what source does it come?—The water consumption for domestic purposes is 21.27 gallons per head, and for manufacturing purposes, 3.90 gallons per head; total, 25.17 gallons per head. The water is obtained from a moorland gathering ground, augmented by springs. The water is impounded in reservoirs.

20697. Is it hard or soft water?—The water is very soft. The hardest of the supplies is as follows: temporary hardness, 3.0 parts per 100,000; permanent hardness, 3.0 parts per 100,000.

20698. What is the drainage area of the part of the town which is sewered?—1,012 acres.

20699. What proportion of the population use pail closets or middens and what proportion use water-closets?—97 per cent. use clean water or waste-water closets; 3 per cent. use tank or pail closets.

10700. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather in winter and in summer?—It has been found impossible to gauge the flow of sewage continually by means of an automatic recording gauge, as the levels would not permit of this being fixed satisfactorily. The flow of sewage has, however, on various occasions been calculated from the depth and velocity in the brick conduits. The results were as follows:—Dry weather flow: Winter, 2,500,000 gallons; summer, 2,000,000 gallons.

20701. What is the maximum dry weather rate of flow, and at what hour does this occur?—At the rate of 4,320,000 gallons per 24 hours between the hours of 12 and 2 and 3 and 5 p.m.

20702. What is the minimum dry weather rate of flow, and at what hour does this occur?—750,000 gallons per 24 hours between 2 and 4 a.m.

20703. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—About 9,000,000 gallons per 24 hours. This rate of flow has been known to continue for more than 24 hours.

20704. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation?—There are 36 storm overflows on our system of sewers. Of these only three are on the main outfall sewer. The others discharge into streams at different parts of the town, and there are considerable variations in the number of dilutions at which they come into operation. Most of these are, however, connected with the smaller sewers, and it is intended to do away with them gradually as the sewerage system is amended. The maximum and minimum rates of flow on the various branch sewers have not been determined.

20705. What is the largest number of gallons of sewage which has passed the last storm overflow and come to your works in 24 hours?—9,000,000 gallons.

20706. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—Yes; it is 2,541,500,000 gallons per year = 6,963,014 gallons per day.

20707. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year, and the volume which passes over your storm overflows?—The volume which comes to the works is approximately 2,000,000,000 gallons. We are unable to make an estimate as to the volume which passes over the storm overflows.

20708. How many gallons of trade effluent enter the sewers daily (24 hours), and what is the nature of these effluents? If you have analytical figures, please give them?—The principal trade effluents going to the Duck-pits works consist of:

Dye effluents - - - - - - - 4,000 gallons per day.
Tannery - - - - - - - - 10,000 „ „ „
Gasworks - - - - - - - - 6,000 „ „ „ for 8 months of year.

The Analyses of these Effluents are as follows :—

	Organic Matter.	Mineral Matter.	
Tannery effluent :			
Suspended matter	308·0	16·0	
Solids in solution	206·0	50·0	
Total solids			580·0
Tannery effluent :			
Suspended matter	43·2	36·8	
Solids in solution	26·8	57·2	
Total solids			164·0
Dye and cleaning effluent :			
Suspended matter	36·0	21·6	
Solids in solution	54·0	62·0	
Total solids			173·6
Dye and cleaning effluent :			
Suspended matter	53·0	53·0	
Solids in solution	320·0	868·0	
Total solids			1294 0

20709. Has your authority framed any rules as to the reception of trade effluents into sewers?—When connections are made to the sewers the Corporation do not permit trade effluent to be discharged, except by special arrangement.

20710. Do you find trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise? If so, would you kindly tell us what your difficulties are?—The only trouble we have had with trade effluents has been at the Altham Works, where the dry weather flow is only 350,000 gallons per day, and where 250,000 gallons of very concentrated dye effluent are often discharged per week. This effluent has for a considerable number of years been held up in one or two tanks (each having a capacity of 100,000 gallons) and run off as each tank was filled. During dry weather trouble was often caused by the excessive amount of dye effluent delivered at the works during a short period of time. The oxygen absorption figure in the final effluent was very greatly increased. Recently the effluent has been run through both the afore-mentioned tanks (as sedimentation tanks), thus arresting large quantities of gelatinous material, and the effluent has continuously run into the sewers. Since this alteration has been in vogue no trouble has been experienced in obtaining efficient purification.

20711. In dry weather what is the average amount of suspended matter in the sewage, and what are the highest and lowest figures, in parts per 100,000?—The average amount of suspended matter in dry weather is 119; the maximum is 186, and the minimum 83 parts per 100,000.

20712. What is the physical character of these solids?—On wet sample: Moisture, 79·31 per cent.; organic matter, 16·14 per cent.; mineral matter, 4·55 per cent. On dry sample: Organic matter, 78 per cent.; mineral matter, 22 per cent.

20713. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—Yes; the average analyses are as follows :—

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Oxygen Absorbed.
1903 Summer	2·733	·889	11·1	7·907
„ Winter	2·062	·659	9·3	8·408
1904 Summer	5·753	1·230	11·7	10·466
„ Winter	2·748	1·114	11·4	13·167

20714. Is it a "strong" sewage, and, if so, what characterises its strength?—The sewage is a strong domestic sewage with high albuminoid nitrogen and oxygen absorbed figures. This is largely due to the great number of waste-water closets in use in the Borough.

20715. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—It is subject to considerable variations in strength, but the tank accommodation is so large that these variations do not affect the quality of our final effluents to any marked degree. The question is answered on the assumption that it refers to a normal weather flow.

20716. How do you think "strength" of sewage as affecting purification is best expressed or measured?—By a full analysis, including the amounts of free and organic nitrogen, suspended matter (organic and inorganic), dissolved solids (organic and inorganic), cellulose, and grease; the three minutes oxygen test as an indication of trade effluents; germicides.

20717. Have you any information as to the bacteriological condition of the sewage in dry weather and in

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storm times?—Only as regards the total number of bacteria present. These vary from about 24 millions per c.c. in dry weather flow to as low as four millions per c.c. during continuous wet weather.

20718. Are there any chemical poisons in the sewage?—There are no chemical poisons in our sewage.

20719. Is the sewage always alkaline?—Yes, except when considerable quantities of dye effluent are being delivered at the works.

20720. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—The amount of suspended matter is first increased and afterwards diminishes rapidly. The following figures were obtained during a storm of four hours' duration, the samples being taken between the hours of 1 a.m. and 5 a.m.:—

Average sample during	Suspended matter.
1st hour	24·8
2nd ,,	80·0
3rd ,,	25·6
4th ,,	5·6

20721. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—The present main outfall sewer was constructed in 1873, but a great proportion of the sewerage of the Borough has been dealt with since that date, and it is being added to each year. There are no sunk places in the sewers.

20722. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this by analyses of the liquid portion in dry weather and in storm times?—Its character is shown by the following analyses:—

During Storm Time.

—	Crude sewage.	Crude sewage after filtration through paper.
Free ammonia - -	1·200	1·200
Albuminoid ammonia -	·640	0·320
Oxygen absorbed in 4 hours at 27° C. - -	10·784	6·708
Total solids - - -	116·0	76·8

During Dry Weather.

—	Crude Sewage.	Crude sewage after filtration through paper.
Free ammonia - -	5·000	4·500
Albuminoid ammonia -	1·760	·960
Oxygen absorbed 4 hours - - - -	21·000	9·750
Total solids - - - -	218·4	98·0

20723. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely-increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—We think that the regulations of the Local Government Board might with advantage be modified to some extent. We quite agree that three times the dry weather flow should be purified on contact beds after passing through the septic tanks. During times of storm, when the flow is greatly increased above this amount, in our opinion it would be better to continue to run through the septic tanks till the streets had been thoroughly washed and the polluted storm water had arrived at the works, after which the remaining portion of the diluted sewage should be passed through detritus tanks and treated on storm beds. A flow equal to the normal dry weather flow should be run during this period through the tanks to prevent the possibility of over-septicism. As we do not advocate, partly on the ground of expense, a tank accommodation greater than 24 hours' dry weather flow, to run more than three times the dry weather flow through the tanks for any time would cause a great increase in the amount of suspended solids of the tank effluent, to the detriment of the contact beds. A method we have found very advantageous in dealing with moderate amounts of storm water is to hold up the storm water on land areas to the depth of about one foot. These areas are in a sequence of three or four, and the settled effluent from the last area is run over a scum board into a storm bed, where it is held in contact for about two hours. When necessary these storm beds can be filled as often as four times a day.

20724. What shape and size are your storm overflows?—In most cases the storm overflows have fixed sills, but in some instances leap weirs have been adopted. The sizes of the overflows are such that the sewers are prevented from being put under pressure during storm times.

20725. Would it be possible to have a standard form of overflow; and how would you fix the point at which overflows should be allowed to come into operation?—We think that overflows should have fixed sills, but in some cases we think it would be advisable to adopt leap weirs, the sills of the leaps being immovable and fixed according to circumstances.

20726. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, and upon the character of the surface soil geologically?—We do not think that it is necessary to consider the configuration of the land if the storm overflows are fixed at six dilutions, because whether the land be hilly or flat, the street washings would be delivered at the works before the flow in the sewer reached the six dilutions. The same remarks apply to the surface of the soil geologically.

20727. Should storm overflows be fixed or movable?—We prefer that the sills of the storm overflows should be fixed, but that they should be capable of being raised should an increase in the dry weather flow necessitate the same.

20728. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case?—We think that in fixing the number of dilutions at which storm sewage may be passed into the stream, the size and nature of the stream should be considered specially with reference to the rate of increase in the volume of the stream and its velocity during storm

times. It is possible, under certain conditions, where the volume of the stream is very great in proportion to that of the sewage, that once the road washings have been disposed of the whole volume of the storm sewage might be discharged into the stream without detriment to it.

20729. If your town is drained on the separate system, what happens to the road water?—The surface water which falls on the front streets and front parts of the houses is drained into the surface water drains which discharge into the stream or the canal at convenient points. That falling on the back streets and the rear portions of the houses is drained into the sewers; the portions thus dealt with are practically equal in area.

20730. Could you give us an analysis of a typical sample of your road water during the early period of a storm?—Yes; the analysis gives:—

Free ammonia	·800
Alb. ammonia	·200
Chlorine	4·0
Oxygen absorbed	5·300
Total solids	71·2
Containing suspended matter	44·0

20731. Have you any information as to the bacteriological condition of the road water?—The above sample contained about 800,000 bacteria per C.C., as shown by gelatine plate cultivation at 20° C.

20732. Do you consider that in certain circumstances this liquid should be purified?—We think it desirable that when possible the first portions of the storm water should be purified, unless the size and volume of the river is such as to render it unnecessary.

20733. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers? Initial outlay as well as annual cost should be borne in mind?—Irrespective of the question of cost, but from a sanitary point of view, we consider that it is necessary that some portion of the rain water should be discharged into the sewers. If the sewers are made sufficiently large to take all the rain water in addition to the normal quantity of sewage, the scouring action during dry weather would be quite insufficient. Further, in hilly districts, where the streets are paved, the surface water collects so rapidly that flooding would ensue in the lower parts of the town unless the drains were abnormally large. As regards the question of cost, in our case, a partially separate system has cost about one-fifth more than if we had constructed a combined system alone. This cost would, of course, vary with the system of drainage adopted. The annual cost of maintenance of surface drains is very small compared with that of the sewerage system. In our case the surface water drains discharge at numerous convenient points into the rivers. The fact that the first washings of the streets discharge into the streams is of course a disadvantage, but in a hilly district like ours the increase in the volume of the stream is so rapid that no nuisance is observable. From these considerations we are of opinion that in most circumstances a partially separate system of sewers is desirable.

20734. Have you had experience of the chemical precipitation of sewage?—From 1893 to 1899 chemical precipitation was adopted, the precipitants being lime and copperas. In 1900 the tanks were converted to the septic system, which has been continued ever since.

20735. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—When sewage precipitated by lime and copperas was treated on contact beds we obtained fairly good results, but we think that better results were obtained by doing away with precipitants and using septic tanks effluents.

20736. Have you tried various chemicals; and can you give any comparative data on the practical value and cost of different precipitants?—Our experience with chemicals other than lime and copperas has been too slight to be of any value.

20737. What was the average analysis of the liquor from your precipitation tanks? What length of time did the sewage remain in the tanks?—The average of four months' analyses is as follows:—

Albuminoid Ammonia	0·972
Oxygen absorbed in 4 hours at 27° C.	7·714

There was about a 12 hours' dry weather flow through the tanks.

20738. Did you find it necessary to add further chemicals to the sludge before it could be dealt with?—It was found necessary to add a certain quantity of milk of lime.

20739. What was the manurial value of the sludge obtained by the chemical precipitation of sewage, and would farmers take it?—The manurial value was principally due to the amount of lime present. It came out at a valuation of about 1s. 2d. per ton for the pressed cake. There was a fair demand for this manure, which was sold at 10d. per ton.

20740. Did it contain any chemical poisons?—No.

20740*. Did you find any nuisance from the treatment of sewage in chemical precipitation tanks? Were any complaints made?—No nuisance was caused and no complaints were made.

20741. As regards septic tanks, what shape should they be?—We have found the rectangular shaped tanks 80 ft. by 46 ft. by 6 ft. 6 in. deep convenient in shape and size for our flow of sewage.

20742. Should they be divided into sections?—We do not know of any advantage to be gained by dividing tanks into sections.

20743. Should they be used in series or in parallel?—This question is to some extent under consideration. At present we are using the first ten tanks, equal to about 9·6 hours' dry weather flow, in parallel, and the effluent from these tanks is then passed through seven other tanks (14·4 hours' capacity), also worked in parallel. It is intended to work all the tanks in parallel at some future time, with a view to ascertaining whether this or the before-mentioned method is the more satisfactory.

20744. Is a scum necessary or desirable?—A scum is, we believe, desirable, although at times when many of the tanks have been without one we have not found any difference in the purity of our final effluents.

20745. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—We have experimented with a concrete covered septic tank and an uncovered septic tank of exactly similar dimensions. The results obtained prove conclusively that with our sewage nothing was gained by covering the septic tank.

20746. What do you consider the best arrangement for the "feed" and "draw-off"?—We have found that the best method is to admit the requisite quantity of sewage at the deep end of the tank by means of sealed inlets so arranged as to give the greatest possible diffusion throughout the tank. The draw-off consists of a sealed outlet and sill running the whole length of the end of the tank opposite to the feed.

20747. At what rate is sewage, as a matter of custom, passed through your septic tanks?—The average flow of sewage through our tanks is about four million gallons per 24 hours, equal to 15 hours' septic digestion.

20748. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous?—The average rate of flow through our tanks is as follows:—Maximum flow of which the duration is six hours at the rate of 6,000,000 gallons per 24 hours or 10 hours' digestion. For the remaining 18 hours of the day, the average of the rate of flow per 24 hours is 3,333,333 gallons, or a digestion of 18 hours. From experiments which we have made there does not appear to be much difference in the effluent between 12 and 24 hours' digestion, and we have attempted to keep our sewage as nearly as possible within these limits. If the flow is too rapid the suspended matter in the effluent is greatly increased, and we see no advantage in more than 24 hours' contact.

20749. Is it possible to "over-septicise" a sewage, and, if so, for what reasons, and how is the "over-

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septicising" brought about?—We have not had in practice any specific instance of over-septicism. It is, however, undoubtedly a fact that if sewage is kept too long in the tanks considerable quantities of sulphuretted hydrogen would be produced, not only causing a nuisance, but interfering with the subsequent treatment of the effluent, by using up oxygen for its oxidation and by interfering with hydrolysis.

20750. What is the amount of digestion in your septic tanks? How far do you find that the digestion is affected by the atmospheric temperature?—We regret that we have not had the means at our disposal to estimate this figure ; slight variations in temperature make no difference, as, although the average temperature in the closed septic tank was somewhat higher than that in the open septic tank (during a period of six months), the amount of sludge formed in each case was practically identical.

20750. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning, and then remove all the sludge?—We prefer to remove our sludge entirely at fairly long intervals, because the greater part of it accumulates at the surface of the tanks.

20752. How often, then, would you clean out the tanks?—The septic tanks are entirely cleaned out every six months.

20753. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—Our practice is as follows:—The liquid portion of the contents of the tank which is to be sludged having been run off, sewage is run on to the settled scum, which is then broken up by means of long wooden rakes. The resultant sludge is then pumped into an adjoining tank which is kept empty for the purpose, milk of lime being added to the sludge at a point adjacent to the inlet of the tank, thus ensuring a thorough admixture of lime and sludge. The sludge is then allowed to settle for about 12 hours, after which the supernatant liquid is drained off. A further quantity of milk of lime is then added to the sludge, after which the whole is pumped into an adjoining sludge tank and pressed in the usual way. The total quantity of lime used for pressing is about 5 per cent. of the wet sludge or 20 per cent. of the pressed cake. For the intermediate tank, it has been found convenient to use whichever of the detritus tanks happens at that time to have been pumped clear of detritus sludge. Owing to the thorough admixture of lime and sludge, no difficulty has been experienced in pressing the septic sludge.

20754. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working—*i.e.*, as the time approaches for removing sludge from the tank?—Yes, we have found this to be the case.

20755. What amounts of suspended solids, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—We have not been working a sufficient time with our full number of tanks to be able to give the required data. With the original 10 tanks (capacity about 10 hrs. dry weather flow) the suspended matter in the tank effluent varied from about 15 parts per 100,000 after a few weeks' working to 35 parts per 100,000 at the end of six months. During the last four months this effluent has passed through four additional tanks (which will shortly be increased to seven), and the suspended matter during times of normal flow has varied between three and seven parts per 100,000.

20756. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—We think that up to three dilutions the sewage should be run through the septic tanks, and after this only until the polluted storm water has been delivered at the works. When this has taken place, a flow about equal to the normal should be allowed to continue to run through the tanks.

20757. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank, and, if so, can you give us figures showing what the increase is?—During the storm referred to in Question 20720 the whole of the storm sewage was passed through the tanks, and samples taken each hour, with the following results:—

	Suspended Solids.
1st hour - - - -	4·0 parts per 100,000
2nd ,, - - - -	8·0 ,, ,,
3rd ,, - - - -	8·0 ,, ,,
4th ,, - - - -	9·6 ,, ,,

20758. May you admit storm sewage to your septic tank, to an extent which raises the ordinary level of the liquid, without serious detriment to the functions of the tank?—As the levels of our tanks can only vary within very small limits we cannot give any information on this point.

20759. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way, as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—We have never used any automatic gear.

20760. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor?—We obtained better results with septic tank effluent than with chemically treated effluent.

20761. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—We have not carried out sufficient work on this subject to make our evidence of any real value. It is undoubtedly very complicated, owing to the action of the sludge and the alteration of the constitution of the dissolved solids.

20762. Have you any data on the relative value of plain septic tanks, and septic tanks filled with rough stones or flints?—No.

20763. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—We have never experienced any nuisance, nor have any complaints been made.

20764. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—We think that it is desirable to remove the solids as far as possible. In our case we get down to between five and six parts of suspended matter per 100,000. When we had only half the number of tanks the suspended matter was very much higher.

20765. How do you consider that the removal of suspended solids can best be effected?—Firstly, by screening to eliminate the coarser material ; and, secondly, by means of large detritus tanks ; then by means of septic tanks of at least 24 hours' dry weather flow capacity.

20766. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?—No.

20767. What other (if any) method of dealing with tank liquor before delivering it to filters do you regard as necessary or advisable?—We have not found any additional method necessary, but the distributing troughs on the contact beds arrest a considerable amount of suspended matter.

20768. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement? I am not sure whether it would be possible for you to make this comparison on the assumption *that in each case you reduce the same sewage down to the same figure for suspended solids*, but if this could be done it would be useful to include a comparison on this basis?—The comparative costs in our case were as follow:—The initial expenses were about the same for both methods of treatment. We cannot speak as to the suspended solids, because we have no figures showing the amount of the suspended matter in the chemical precipitation effluent, but judging from the appearance it was only slight. The following statement does not include any payments in respect of principal or interest

on loans, but only the actual annual working expenses:—

	Chemical Precipitation.	Septic Tanks.
	£ s. d.	£ s. d.
Lime precipitation and pressing	742 0 9	346 17 8
Copperas	96 15 4	—
Coal	253 10 3	185 5 8
Press cloths	155 0 0	113 2 8
Wages	683 16 0	485 17 0
	1,931 2 4	1,131 3 0
Less receipts for manure	317 12 0	150 4 0
	1,613 10 4	980 19 0
Cost of treatment per million gallons of dry-weather flow	£2 4 2	£1 6 8

When we were using precipitants we got more than twice the amount of sludge that we do at the present time from the septic tanks. The pressed cake produced during the time of chemical precipitation averaged about 7,500 tons per annum. By the present system of working we obtain:—

2,795 tons of pressed septic sludge cake per annum.
8.0 „ „ detritus „ „ „

Total 3,605

The purification from the chemical effluent was not quite so satisfactory on contact beds, and considerable quantities of hydrated oxide of iron were deposited in the bed. It is quite conceivable that with certain kinds of trade effluents some method of precipitation has to be resorted to, though we have had no practical experience of this.

20769. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—We consider that where the subsoil is of a heavy character all building materials may be satisfactorily dispensed with, except for the construction of the outlet chamber.

20770. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—Although we have no personal experience with beds of a greater depth than three feet, we think that if increased much beyond this limit solidification of the lower stratum would take place, and the drainage of the bed would be interfered with. The aeration would also be less perfect, and the capacity of the bed would probably diminish more rapidly.

20771. What do you consider is the most convenient size for a contact bed?—The size of each bed should be such that it can be filled by the available flow of tank effluent in about two hours.

20772. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—We prefer to use hard-burnt clinker to any other material.

20773. What size should the filtering material be, and should it be graded in the beds?—We consider it necessary that all material used in the construction of contact beds should be both washed and screened. For the first contact beds, we use all material which is retained by a screen of half-inch mesh. Any large lumps are first broken, as they interfere with the screening machinery. For the second contact beds, the material passing through a half-inch mesh and retained by a ⅛in. mesh is used. No attempt is made to grade the material in the bed, but in filling the material into the bed the coarser clinker inclines to accumulate in the lower portions of the bed.

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20774. How should the bottom of the bed be constructed?—The bottom of the bed should be excavated so as to allow of a good fall towards the outlet chamber. The drains are laid on the surface of the ground in herring-bone fashion, the under side of the pipes being laid in a grip. We have found it desirable to use glazed and socketed earthenware pipes with half-inch holes three-quarters of the way round the pipe. The main drain is laid with a fall of 1 in 200 towards the outlet chamber, and the branch drains have an inclination of 1 in 600. In secondary beds unglazed field tiles with butt joints have been used with satisfactory results.

20775. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—We believe that some form of tank treatment is requisite.

20776. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary beds and for secondary beds?—With our sewage we have found for both the primary and secondary beds a period of about two hours' filling followed by a two hours' contact to be most satisfactory. We work two cycles per day, the beds standing empty not less than two hours between fillings.

20777. How should contact beds be filled and emptied?—We think that the most important point to be considered in filling a bed is perfect distribution combined with moderate aeration of the inflowing liquor. This we have obtained in a most satisfactory manner by means of troughs fixed 6ft. to 8ft. apart. The troughs are fixed on the surface of the bed, and can easily be re-adjusted in case of settlement. The effluent runs gently over the sides of the troughs which have no perforations. Facilities are provided for emptying and cleaning the troughs. In emptying a bed we open the outlet valve to its full extent, thus emptying the bed as quickly as posible.

20778. Have you had experience of automatic gear for filling and emptying contact beds?—We have not used any automatic apparatus for filling or discharging. The reasons which have led to the exclusion of automatic apparatus are as follows:—

(1) They are very liable to get out of order, and consequently it is necessary to have a man always on the watch to see that they are working properly. As the attendance of one man is all that is required at our works to control the valves, no saving of wages would be effected, but there would be a considerable increase in capital outlay, as all these appliances are expensive to instal, and we think costly to maintain.

(2) Automatic apparatus takes no notice of the condition of the bed, which, in our opinion, is a matter of considerable importance.

(3) Where the flow of sewage varies it is desirable to be able to bring the larger beds into use during the time of the greatest flow, so that their period of filling may approximately equal that of the smaller beds. This we consider is best accomplished by hand control.

20779. What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed in 24 hours? If the amount varies with the quality of the tank liquor, please state by analytical figures what quality you are assuming, and how differences in the tank liquor affect the amount that can be properly treated?—Assuming that the bed has been made in conformity with our former recommendations (*see* No. 20773), we can treat 90 gallons per cubic yard (with two fillings) per 24 hours. When the strength of the tank liquor falls below about ·400 parts per 100,000 of albuminoid ammonia and 7·000 parts per 100,000 of oxygen absorbed (in four hours) about 45 gallons more per cubic yard can be treated.

20780. What amount of liquid from a primary bed can, in practice, be properly treated on each cubic yard of filtering material of a secondary bed in 24 hours?—Taking a typical second contact bed which has been in operation for 5¼ years, we obtained a gauging of 45·5 gallons per cubic yard capacity, and there has been no difficulty in maintaining this. We can therefore treat 90 gallons per cubic yard per 24 hours with two fillings.

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20781. Can these quantities be increased by more frequent filling and emptying in times of storm without impairing the efficiency of the beds or the quality of the effluents?—With our sewage we do not consider that we could advantageously fill the beds more than three times a day without impairing the quality of the effluent.

20782. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent?—We have had no experience of sewage that could be so treated.

20783. At what rate or rates do primary contact beds and secondary contact beds lose their water-holding capacity?—No. 5 first contact bed, made of washed and re-screened material, recommenced working on June 15th, 1904. The following table gives the numerous gaugings which have been made of the capacity of this bed :—

FIRST CONTACT BED No. 5.

Contents of bed, 3,081 cubic yards, 519,912 gallons

Date of Gauging.	Number of Filling.	Total Capacity in Gallons.	Percentage Capacity Empty Bed—100.	Capacity in Gallons per Cubic Yard.	Remarks.
1904.					
June 15	1	243,644	46·79	79·08	
„ 16	3	237,640	45·64	77·13	
„ 20	11	225,234	43·25	73·10	Beds not properly drained.
„ 21	13	227,090	43·61	73·70	
„ 24	19	217,965	41·85	70·74	Showery.
July 1	32	211,122	40·54	68·52	„
„ 7	44	210,959	40·51	68·47	
„ 14	58	209,508	40·24	68·00	
„ 30	89	207,272	39·81	67·27	
Aug. 4	100	201,405	38·68	65·37	Showery.
„ 11	114	194,417	37·33	63·10	
„ 18	128	193,094	37·09	62·67	
„ 25	142	186,131	35·74	60·41	
Sept. 1	156	185,600	35·65	60·24	
„ 8	170	183,688	35·27	59·62	
„ 15	184	173,759	33·37	56·39	
„ 22	198	173,382	33·29	56·27	
„ 29	212	170,757	32·79	55·42	
Oct. 6	226	168,918	32·45	54·82	
„ 13	240	167,728	32·20	54·43	
„ 20	254	160,486	30·81	52·09	
„ 27	268	160,375	30·79	52·05	
Nov. 3	282	156,126	29·98	50·67	
„ 10	296	155,970	29·94	50·62	
„ 17	310	157,055	30·15	50·97	The bed had 45 minutes extra rest on this date.
„ 24	324	154,820	29·72	50·24	
Dec. 1	338	154,505	29·67	50·16	
„ 8	352	154,039	29·58	49·99	
„ 15*	366	150,761	28·95	48·93	
„ 28	383	172,864	33·20	56·10	Bed rested 4½ days.
1905.					
Jan. 26	426	160,220	30·77	52·00	Bed rested 7½ days.
Feb. 23	484	151,669	29·13	49·22	

No. 18 first contact bed was formed of unscreened furnace clinker, and commenced working in January, 1898. For a period of about six months it was used without troughs, otherwise distribution has always been by means of wooden troughs.

* The bed completed six months continuous working at two fillings per day on this date.

The following gaugings have been taken :—

Date of Gauging.	Total Capacity in Gallons.	Percentage Capacity in Gallons. Empty Bed—100.	Capacity in Gallons per Cubic Yard.
June 13, 1899 - - - - -	108,255	25·6	43·0
September 25, 1900 - - - -	65,374	15·8	26·5
November 13, 1900 - - - -	69,800	16·8	28·3
October 10, 1902 - - - - -	61,300	14·7	24·8
March 20, 1905 - - - - -	56,786	13·7	23·04

20784. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed or to the fineness or coarseness of the material of the bed, or on what does it depend?—The loss of capacity, in our opinion, is due to the following causes :—

(a) The formation of gelatinous matter on the surface and in the interstices of the material, but necessary for the purifying action of the bed.

(b) The non-destructible suspended matter carried into the bed.

(c) Disintegration of the clinker and the consolidation of this disintegrated material to a spongy mass. In our opinion this accounts almost entirely for all further loss in capacity after the bed has once arrived at maturity.

(d) The accumulation of irreducible humus gradually deposited from the sewage. The weathering or wasting of this material probably accounts for the increase in suspended matter occasionally noticed in contact bed effluents.

20785. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard?—Yes, without difficulty. We have washed several beds of over a half acre in area in the following manner An inclined rotary screen 10ft. by 4ft. is fixed at a suitable elevation and so constructed as to be easily capable of removal from bed to bed as required. The whole is arranged so as to admit of washing, grading, and screening the clinker as required The material excavated from the bed is tipped into a boot fed with tank effluent, and is raised therefrom by elevators to the screen. There it is washed and graded in the way explained in reply to Question No. 20773. The wash water is run into a large wooden trough, where most of the fine material settles. It is subsequently purified on land areas and secondary beds. The power is supplied by a portable engine. The total cost of the screening machinery and engine and shed was £280. This machinery is capable of dealing with 100 tons of material per day of nine hours. The cost of screening a bed of 0·65 acres was at the rate of 1s. per cubic yard of the capacity of the bed. This includes excavating, packing troughs, wheeling, screening and washing not only the material excavated but also the additional material required to take the place of the portion rejected, and filling the same into the bed. This cost, although inclusive of fuel, does not include any interest on capital outlay. The following tables show the quantities of the various grades of material obtained by screening the clinker from the bed (the material of which had been dry screened when the bed was first made), and also from the screening of new furnace clinker collected from mills :—

Material from the Old Bed.

Material above ½ in. used for first contact beds - - - - - - -	60 per cent.
Between ⅛ and ½ in. used for second contact beds - - - - - - -	30 ,, ,,
Below ⅛ in. rejected - - - - - -	10 ,, ,,

New Furnace Clinker.

Material above ½ in. used for first contact beds - - - - - - -	40 ,, ,,
Between ⅛ and ½ in. used for second beds	38 ,, ,,
Below ⅛ in. rejected - - - - -	22 ,, ,,

20786. How can the capacity of contact beds be best maintained?—

(1) By efficient drainage.

(2) By the use of material which will not disintegrate.

(3) By filling the beds quietly and evenly, and as far as possible preventing the entrance of suspended matter.

(4) By allowing judicious periods of rest during which time the bed should be allowed to drain thoroughly.

(5) By keeping the surface of the bed in good order so as to prevent flooding.

20787. What is the average analysis of your single contact effluent and your double contact effluent?—The average analyses are as follows :—

——	Albuminoid Ammonia.	Oxygen absorbed in 4 hours at 27° C.	Nitric Nitrogen.	Chlorine.
Primary Beds—				
1902 - - - -	0·244	1·893	0·166	7·5
1903 - - - -	0·264	2·498	0·227	7·9
Secondary Beds—				
1902 - - - -	0·089	0·757	1·068	7·7
1903 - - -	0·072	0·799	1·056	7·9

20788. What number of gallons of liquid are treated daily per cubic yard of filtering material in your first bed, and what number of gallons are treated daily per cubic yard of filtering material in the two filters?—The number of gallons we can treat daily per cubic yard is 90 for first contact beds (two fillings). The quantity treated daily per cubic yards of filtering material in the two beds by two fillings is 45 gallons.

20789. Do you find any chemical poisons in your effluent?—No.

20790. What is the average amount of suspended matter in the primary bed effluent and the secondary bed effluent? Does most of this suspended matter come out with the first flush or not?—In the primary bed effluent the suspended matter averages 3 to 4 parts per 100,000. Second contact bed effluent averages about 1

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part per 100,000. The first flush of the second contact bed contains about 4 parts per 100,000. This rapidly diminishes.

20791. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed is different from the organic matter of the suspended solids going on to that bed?—We have made no comparisons.

20792. Is the first flush of effluent from either set of beds ever putrescible?—The first flush from our first contact bed is generally putrescible; that from the second contact beds practically never.

20793. Do you find that by increasing the number of fillings in storm times or other times, the amount of suspended solids is increased?—The suspended solids in the final effluent vary from 0·4 to a maximum of 2·8 parts per 100,000. Storm water does not seem to have any effect on the final effluent in this respect.

20794. May contact beds in time of storm be used as streaming filters without detriment to their customary efficiency?—We consider that this would be very detrimental to the subsequent working of the bed.

20795. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per twenty-four hours in ordinary times and in storm times?—The cost per acre is £1,300. The amount treated by double contact on beds three feet deep is 217,800 gallons per acre.

20796. Have you made any experiments which throw light upon the action of contact beds when full and when resting?—No. At the same time, we believe it has been proved that certain growths within the bed have a very powerful affinity for oxygen.

20797. Have you made a study of the conditions of aeration of contact beds, and, if so, with what results?—We have found that we can only get satisfactory results when distribution is good and when moderate periods are allowed for the aeration of the bed.

20798. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—No nuisance is caused, nor have any complaints been made.

20799. Could you make a comparison of the cost and relative advantages of percolating filters and contact beds?—We have no personal experience in percolating filters, but from results supplied by Accrington, and published in Dr. Fowler's paper read before the Sanitary Congress at Glasgow (1904) the cost per million gallons, calculated on the dry weather flow, is £3 7s., the percentage improvement effected on the tank effluent being about 76. The cost per million gallons by our double contact system is £3 7s. 6d., the percentage improvement being 85 on the tank effluent. This has been calculated as follows :

Total expenditure - -	£2,866	8	0
Less receipts from manure and crops	400	8	6
Net cost - - - -	2,466	0	0

These figures do not include interest on capital outlay. Dry weather flow is 2,000,000 gallons.

20800. Can you say whether the chance of nuisance is any greater with one form of filter than with another?—We have had no personal experience in working percolating filters. The contact beds at our works have never caused any nuisance, although we have a strong sewage to deal with.

20801. You have not made any comparative observations as to the amount which can be satisfactorily purified by the two forms of filter?—No.

20802. Could you express an opinion as to how the number of gallons which can be treated would vary with variations in the strength of your tank liquor, and on what figure or figures you would rely for defining the "strength" of your tank liquor?—The strength of the tank effluent in reference to the number of fillings would be gauged by the volume of sewage arriving at the works as compared with the normal flow (*see* also No. 20779).

20803. Have you had any experience of storm water filters?—We do not use storm filters as streaming filters at present, but as single contact beds after the effluent has been settled on land areas. By this method we have been able to keep the effluents within the Ribble Joint Committee's standard (*i.e.*, 0·150 albuminoid ammonia).

20804. Do you consider storm water filters lose any of their efficiency by being used intermittently at long intervals?—We prefer to give our storm beds at least three fillings per week, as otherwise we find that they do not work satisfactorily.

20805. Have you any practical suggestions to make for disposing of sludges?—Sewage screenings in our case are dug into the land adjoining the works, which is owned by a market gardener. The quantity is not great, being about 250 tons per annum. As regards other kinds of sludge, the only way we have found at all practicable is to press all sludge, whether detritus, precipitation, or septic tank sludges, and to dispose of the cake thus made. This cake is mechanically disintegrated, so as to be ready for use by the farmers. At present we are able to sell all our cake at 10d. per ton at the works. When we used chemical precipitation, the amount of sludge being much greater, we were sometimes obliged to dispose of a portion of it by sending it by canal ten or twelve miles into the country. We consider that the only practical way for sludge to be dealt with by inland towns is by pressing : 90 per cent. of the moisture is thus disposed of, rendering the material much more suitable for any subsequent method of disposal. What this latter method should be must be decided by each town according to the circumstances.

20806. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?—The disposal of sludge by natural drying is in our opinion likely to cause a nuisance.

20805*. What, in your opinion, constitutes a good effluent?—We should consider that the following factors are requisite for a good effluent :—

(1) That it does not contain any appreciable quantity of suspended matter.

(2) That it is non-putrescible under ordinary climatic conditions.

(3) That it does not deposit any sediment on standing, even after admixture with aerated water.

(4) That it should contain sufficient dissolved oxygen for the support of fish life.

(5) That it should contain sufficient nitric nitrogen to meet the requirements of the organic matter still remaining in the effluent.

20807. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—We are of the opinion that the contact bed effluent is superior to that from a percolating filter, for the following reasons :—

(1) It is not so liable to deposit on standing or on subsequent dilution.

(2) The organic matter present in it is less putrescible than that present in a percolating filter effluent without subsequent straining, and consequently less call is made on the nitric nitrogen.

(3) The purification effected in strong sewages by double contact is considerably greater than by a percolating filter.

(4) It is also probable, admitting that pathogenic organisms are largely destroyed by the presence of overwhelming numbers of other organisms, that the prolonged contact in bacteria beds is more inimical to their development than the short period of contact on the percolating filter.

20807*. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—We rely upon the following tests :—

(1) The amount of probably putrescible matter as measured by the albuminoid ammonia and oxygen absorbed tests.

(2) The total purification as measured from the improvement effected on the albuminoid ammonia on the crude sewage, because the greater the purification effected the less liable is any remaining organic matter to subsequent putrefaction.

(3) The amount of nitrification which has been effected, and the condition of this nitrogen

(whether nitrous or nitric), because this figure shows not only the state of purity at which the sewage has arrived, but also what reserves it has to draw upon.

(4) The rapidity with which an effluent absorbs dissolved oxygen, either with or without dilution. This test shows whether the effluent is likely to be inimical to fish life or not by making any subsequent call upon the oxygen of the stream.

(5) The amount of suspended matter in the effluent and the proportion of organic to inorganic, as nuisance may be caused in the stream owing to the deposit of such material.

20808. Have you tried the "aeration" test, *i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—Yes; we have supplied the Commission with a series of figures we obtained from this test (*See Appendix*, page 71).

20809. Is one standard for all effluents passing into non-potable streams possible and desirable?—No; we do not think it possible.

20810. Should there be more than one standard, and, if so, how should a plurality or series of standards be formulated?—We consider it would be advisable to have a plurality or series of standards which would take into consideration the strength and volume of the sewage and the velocity and volume of the stream at the time of discharge. The standards to be adopted might be arrived at by mutual arrangement between the rivers authority and the local authorities. In case of dispute the matter should be referred to the Local Government Board or some specially constituted authority for arbitration.

20811. What is your experience of the effect of storm water upon filters of various sorts?—We have not made any experiments in the use of storm water beds other than those mentioned in reply to question No. 20723.

20812. How far do you consider it advisable for a sewage installation to be worked automatically?—We do not approve of automatic installations in works of any size. In small works they may sometimes be necessary on economical grounds; but even then frequent supervision is necessary.

20813. Have you made any systematic observations as to the effects of discharging effluents into watercourses?—No. As regards possible damage to fish life from effluents, we may say that a number of small fish were kept in a tank fed by second contact bed effluent only, for a period of nine months. During this time they were quite healthy. They were finally washed away by an excessive flood.

20814. Could you make a short statement setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents, and giving your reasons?—The four hours' oxygen test is a useful comparative test where sewages of the same character are being examined daily. The albuminoid ammonia is a still more useful figure for judging the amount of treatment that the sewage is likely to require or the amount of unfermented organic matter present in an effluent. A nitrogen determination by the Kjeldahl method is, however, much more satisfactory than this latter, because the ratio of albuminoid nitrogen to the total nitrogen obtained varies enormously with the strength and condition of the sewage. The three minutes' oxygen test is a useful indication of the amount of trade effluent in the sewage. For effluents the dissolved oxygen test is of the greatest possible value. The simpler the method the better. The rate at which oxygen is absorbed by the effluent during given periods of time is one of its most valuable applications. The nitrites and nitrates indicate the reserve which the sewage has to draw upon independently of the dissolved oxygen, and also to what extent the sewage has been purified.

20815. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—The most important points to be determined in a crude sewage are the suspended matter and the ratio of organic to inorganic matter in the same. This will give some idea as to the quantity of sludge which has to be dealt with. The saline and organic ammonia should be determined as an indication of the organic strength of the sewage. The three minutes' oxygen absorbed should be used as an indication of the amount of trade effluent. The determination of the amounts of grease and cellulose would also be most useful, and in some cases absolutely necessary.

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TANK LIQUOR.

In the tank liquor an additional amount of ammonia should be found, and there should be a considerable diminution in the amount of suspended matter. An increase in the oxygen absorbed would indicate over septicism.

PRIMARY CONTACT BED EFFLUENT.

It depends to a large extent upon how it is to be subsequently treated. In working with double contact the first contact bed continues in a measure the action of the septic tank, but aerobically instead of anaerobically. We should look for a decrease in the free ammonia of 40 per cent to 50 per cent., and about the same on the albuminoid ammonia. Hydrolysis is requisite, but not nitrification.

SECONDARY CONTACT BED EFFLUENT.

The free albuminoid ammonia should be reduced as low as possible, indicating that little fermentable matter is present. The oxygen absorbed figure should also be low for the same reason. The nitric nitrogen should be high, as it indicates how far organic nitrogen has been converted into inorganic nitrogen.

20816. (*Chairman.*) On question 20713, do you know why the sewage was stronger in 1904 than it was in 1903?—(*Mr. Raymond Ross.*) Yes; there was a very much greater rainfall in 1903 than in 1904—very considerably; 1903 was a very wet year, 1904 was a very dry year, one of the best years we have had.

20817. (*Mr. Power.*) Are these averages of the months, then, for each year?—Yes, sir; we took samples every day; some days two lots of samples completely through, and at the end of the month they are all returned to the Highways and Sewage Committee with all the analyses—all the details of them—and they are all averaged up, and this is the average of the averages.

20818. You add together twelve monthly averages and divide by 12?—We add the whole twelve months together and divide by 12; about 2,700 analyses per year are included in this.

20819. Are included in this?—Are included each year; about 2,500 to 1,700 are included each year, and these are the average of these analyses.

20820. (*Chairman.*) Then question 20716, do you think that any one figure would give you a fairly approximate idea of the strength?—I think it might, as a rule, in any district where you knew the circumstances, but I think the figure might have to vary according to the district in which it was being taken; that is to say, you would have to take cognisance of the method of purification which was adopted and the original strength of the sewage.

20821. Question 20720, I see these figures are lower than your average of suspended solids in dry weather, and I suppose that is due to the fact that in the very early part of the storm the sewage, apart from the storm, would contain very few suspended solids, and that these given in the table are almost wholly due to the storm?—Yes, my Lord, that is it, and there were not quite so many. We have not had a large number of analyses. We did not get these questions in time to take a very large number, and they were taken under conditions that just existed at the time; but the other ones have been taken over a long period, and consequently they are hardly comparable between each other. It was a question in your questions that suggested doing what we could in the time that we had before sending in the answers.

20822. (*Mr. Power.*) The figures given by you in reply to Question 20720, those are storm sewage figures, not storm water proper, are they?—They are.

20823. The average sample during the first, second, third, and fourth hour; it is Question 20720?—These are tank effluents.

20824. They are tank effluents?—Tank effluents.

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20725. Your minimum in Question 20711 was 83 parts?—No, I am wrong, sir; they are not tank effluents, they are crude sewages; these are crude sewages.

20726. Containing a very large proportion of storm water, I suppose?—Containing a very large proportion of storm water. We get ours very quickly, because it is very hilly, and all the streets are paved, so the storm water arrives very quickly at the works and in considerable volume, and only a short sewer. (*Mr. G. H. Pickles.*) It is about one and three-quarter miles from the centre of the town.

20827. (*Chairman.*) I am not quite certain of Question 20723. You do not appear to me to state quite definitely whether running the first part of the storm sewage through the tanks and filters is likely to cause damage or not?—(*Mr. Raymond Ross.*) No; I think not, my Lord; as long as it goes through the tanks I do not see that it can do any particular harm if your tank capacity is sufficient. The thing is not to throw your suspended solids up too highly in the effluent from the tanks—the tank effluent. You see every 12 parts of suspended matter means that for two million gallons it would work out to a cubic foot of material carried into a bed; so I think it is purely a matter of how big your tank capacity is so as to get rid of a sufficiency of suspended solids.

20828. (*Mr. Power.*) But do you, as a matter of fact, pass much storm sewage through your tanks? I see your dry weather flow is 2,500,000 to 2,000,000, and your maximum in 24 hours is 9,000,000. Do you take four times the dry weather flow through the tanks, as a matter of fact?—Three times the dry weather flow; then the big detritus tanks; at the side we have two very large detritus tanks, and those have long sills which overflow at three times the dry weather flow, so that by regulating the sluices which lead into the septic tanks we can send three times through the tanks continually, and let the rest overflow after passing through the big detritus tanks.

20829. After passing through the big detritus tanks then that goes to the ponds you speak of?—It joins with the other effluent. Unfortunately we have no separate channel, although in our scheme we have provided for another channel to take this water separately. That is not yet constructed, but it is intended to deal with the water separately to the overflow water. At present it is simply allowed to mix with the other. (*Mr. Pickles.*) Of course, all the sewage which arrives at the works must pass into one or other of the detritus tanks, but there is an overflow from those detritus tanks which intercepts the sewage—that is, the storm sewage—so that only three times the dry weather flow passes through the septic tanks proper. Then, of course, the overflow joins the main conduit again, mixes with the tank effluent, and then runs in the common conduit to the farm. Then, of course, part is dealt with on the contact beds, and the remainder on these land areas.

20830. Is the 9,000,000 gallons that comes down to you in 24 hours now the maximum that the sewers will carry?—Well, the conduit has been running within four inches of the top; it is practically the maximum that the sewers will carry. Of course, storm overflows would be working at that time.

20831. You are contemplating doing away with some storm overflows and raising others, so in time to come you will have more to deal with in storm than now, will you not?—We shall, sir.

20732. And so far as the sewers will carry it you deal with that on your present plan. You now deal with some of it in the ponds. Do you not let that extra amount go into the tanks? Will not your storage at the works have to be bigger the more storm water you get down in the 24 hours?—In any case, we would only take three times the dry weather flow through the septic tanks, and then the remainder, after passing trough the detritus tanks, would be carried by the separate storm water conduit to the farm, which is three-quarters of a mile lower down, and dealt with on the land.

20833. On the land?—So that the storm sewage would not mix with the tank effluents.

20834. Quite so?—It would be separate from the tank effluents.

20835. Three volumes would be dealt with, and other three, five, or additional volumes would be dealt with in this way?—Yes, sir.

20836. (*Chairman.*) Then, in your answer to Question 20735, you say when sewage, precipitated by lime and copperas, was treated on contact beds, you obtained fairly good results; but you think that better results were obtained by doing away with precipitants and using septic tank effluents. Well, now, do you speak positively on that point?—(*Mr. Ross.*) Yes; I think I may speak positively on that point in this way: that although I did not do all the analyses (I had not come there when a number of the analyses were done) still copies were lent to me of these analyses, and I know it was my predecessor's opinion, although he only had a very short experience; in fact, a month or so. He only tried it on quite a small scale, and the results we obtained afterwards were undoubtedly very much better, or considerably better; I will not say very much better. They were distinctly better right throughout.

20837. (*Mr. Power.*) But you have distinctly less suspended matter in the effluent from the chemical precipitation tanks?—There would be less suspended matter, but I think now that we have enlarged our tanks we have still reduced the amount of suspended matter sufficiently.

20838. Your septic tank effluent, what does that contain now?—Five to seven parts per 100,000 on the normal weather flow; I do not mean the dry weather flow, but a normal weather flow.

20839. The suspended matter in the raw sewage is very high indeed?—In the raw sewage it is very high indeed, but then we have, you see, rather over 24 hours, really.

20840. Rather over?—It is a little over 24 hours' dry weather flow, and we have taken a considerable number of estimations of suspended matter, and it will vary from five to seven, except during times of prolonged storm, when it goes gradually up, and the highest we have had is nine.

20841. From the septic tank?—From the septic tank. Of course you must still remember that we are not in the position of having a separate conduit yet; it has not been built, so that what arrives at the works at the present moment will contain more suspended matter because it has the overflow from the septic tanks mixed with it.

20842. You mean more than three volumes will go through the septic tanks then?—No, I do not mean that, sir; but the overflows from the detritus tanks mix with the septic tank effluents, because we have not built the new conduit.

20843. It comes to the filters?—It comes to the filters; we cannot help that at present till we get this fresh conduit. It is simply unfortunate that it is so, but it does not interfere with the fact that we can bring our tank effluent down to three to six parts, to an average of five to six parts of suspended matter, taking three times the dry weather flow. (*Mr. Pickles.*) I can support what Mr. Ross says with regard to the result of the chemical precipitation. Of course I took part with Mr. Harris, who was Mr. Ross's predecessor in these experiments, and although I have not the figures I remember that the albuminoid ammonia is distinctly less than it was before.

20844. (*Colonel Harding.*) Were the conditions the same; was there the same length of contact; were all the conditions the same?—Yes; there was not quite the length of septic tank contact, because there was only the old set of tanks working.

20845. Might not it be that the conditions of the first experiment were different from those of the last experiment?—There was about the same contact with the septic tanks.

20846. Was the material the same; were there the same filters, or were they analogous filters?—These filters were the same. (*Mr. Ross.*) I think I know which the filters were—the ones really that most of my ideas were based upon were No. 19, which is still working; it is absolutely the same bed, as it has never been touched.

20847. Anyway the experiments were not simultaneous; they were at some hours' interval?—Oh, not simultaneous. (*Mr. Pickles.*) Oh, no; of course the precipitation was in vogue; but then, of course, it was changed to the septic treatment.

20848. You are comparing the present results that you obtain from septic effluent filtration with the

results obtained some time ago by the filtration of precipitate?—Yes, that is so; we get a clearer tank effluent certainly with chemical precipitation.

20849. (*Mr. Power.*) The effluent from the precipitation tanks was at that time greatly in excess of the effluent from the septic tanks?—No, it was about the same, sir.

20850. (*Colonel Harding.*) Was the volume which you passed the same; was the sewage about the same strength—Yes, it was about the same strength as far as I remember.

20851. Your answer interests us because it differs from the opinion which has been formed elsewhere?—Of course I am simply basing my answer on the albuminoid ammonia figures; those were what we chiefly relied on at that time, and those are what we have submitted to the Committee.

20852. We take it that you have made no simultaneous experiments for the purpose of ascertaining the comparative results?—You may, sir.

20853. You have not made?—Yes. (*Mr. Ross.*) We did find one thing, sir, which is perhaps important, and that is that when using precipitants we got a considerable amount of iron deposited in our contact beds, particularly in the second contact beds; it did not seem to come down so much in the first as in the second contact beds.

20854. And do I gather that you found the septic action more useful in precipitating iron?—Oh no, this was adding copperas.

20855. Oh, I see?—This was adding copperas, and then iron came down and went towards filling the bed; that was all—not interfering with purification.

20856. You have no iron salts coming down in your sewage?—None at all, sir.

20857. (*Mr. Power.*) It was detrimental to the beds, you mean?—Detrimental as regards filling up the bed, as regards causing filling.

20858. (*Chairman.*) You got rid of all your sludge, what I may call your precipitation sludge, at 10d. a ton; can you get the same price for what may be called septic sludge?—Yes, my Lord, we get exactly the same. The lime is of principal value. Our country round has very little lime, and the farmers really like this because of the fibre in the lime mixed together; the amount of fibrous material in the lime; it suits their land and makes it lighter and better.

20859. Then with regard to Question 20744; you say, in reference to septic tanks, "scum is, we believe, desirable." Do you believe that very firmly?—I do believe it rather firmly, but I do not know that I can give any very definite reason for doing so.

20860. (*Colonel Harding.*) Perhaps you would indicate a reason why it is of value. You say, do you not, that you have not found any difference in the purity of final effluents when there is and when there is not a scum?—No, we have not.

20861. Seeing that there is no difference, why is it desirable to have one?—Well, I think in one sense it prevents the variations of temperature, which must really affect purification, although we may not be able to detect it. Sewage is always varying in strength, and you are taking more or less of an average, and it is very difficult to compare one week's flow with another week's flow unless you have very accurate gaugings, which unfortunately we have not.

20862. Am I right in thinking that you think scum is useful in conserving the heat of the sewage?—Yes, in conserving the heat of the sewage more than anything else, and so obtaining a more even temperature.

20863. (*Mr. Power.*) You do not think covering the tank is of any advantage, do you?—I do not think it is of sufficient advantage. It keeps the temperature a little more even, but nothing else; it does not get rid of any more sludge; there is no nuisance when it is not covered, and therefore it is a big expense for practically nothing.

20864. (*Colonel Harding.*) You have not tried whether there is any difference of temperature in the presence of scum and in its absence?—No; I have tried in a covered septic tank, an ordinary tank, and the temperature in the covered septic tank is invariably a few degrees higher. I have for 12 months the figures taken twice daily, and the average was some few degrees higher in the covered septic tank.

20865. (*Mr. Power.*) With and without scum have you tried it?—No, we started it as soon as a thin scum got formed; we did not take it till the thin scum had formed.

20866. (*Sir William Ramsay.*) Does your scum come and go; does it occasionally appear and disappear again?—Only at the very beginning. If it once forms anything like an inch thick it will never go again—it stays.

20867. (*Chairman.*) Well, at Question 20755 you found the suspended matter in the tank effluent rose to about 35 parts per 100,000 at the end of six months. Now, I suppose, you would consider 35 parts was an excessive amount to put on to a contact bed?—Yes, my Lord, very excessive. This is why we made our tank capacity so much bigger.

20868. Then Question 20769. I presume from your answer you do not find that the soil in any way tends to work out into the filters?—Not in the very least. We dug down for several people to see them, and I think everybody who has seen it has been convinced. (*Mr. Pickles.*) In fact, we have dug down to put in perforated pipes in many places instead of the ordinary field tiles, and we have not found the bottom to work up, neither have we found it in the washing and cleaning of a bed; we have taken the material out without any difficulty.

20869. (*Major-General Carey.*) Can a contact bed be considered absolutely water-tight?—(*Mr. Ross.*) Yes, sir, absolutely. We have tested that in this way with the pipes coming up at the end of the herring-bone, so that we can dip these pipes and take a dip on to a stick; take that at the end of two hours, and you will not see any difference that you can possibly detect—in fact, there has been no difference found.

20870. When the bed is empty during periods of rest is there no evidence of leaking when it is exposed to the sun?—It does not seem to; it never has done; we have never had any leaking. The only leaks we have ever had—the whole of the land was originally under-drained, and sometimes one of these, in making a new bed, had been missed out, and then when the new bed started a leak has been found, and it has always turned out to be one of these old under-drains; of course, we have had to go down till we found it, and stop it, and then there has been no further bother.

20871. (*Chairman.*) Then my last question is on 20807. In answering Question 20799 you mentioned that you have had no personal experience of percolating filters; well, then on 20807 you give us the differences between the effluents from a contact bed and the effluents from a percolating filter, and I only just wanted to know what you go upon?—Well, I thought I had stated the results were given to Dr. Fowler, of Manchester, when he was going to read a paper before the Sanitary Congress at Glasgow. He asked several works, and amongst others ours and Accrington. Well, I got, of course, naturally a copy of his paper; I was also there when it was read, and they gave their cost and their purification according as they are set down in this report; they gave their purification as 75 per cent. on the tank effluent at Accrington.

20872. Yes. Did you take the qualities of the effluent from the same standpoint?—From the same standpoint, because the two towns are very close together and very similar. I think it is fair; they are only about six or seven miles apart, and they are both Lancashire mill towns. One is perhaps twice the size of the other, but that is practically as far as I know the only difference. They are worked on very similar lines, and therefore I thought they were comparable.

20873. (*Colonel Harding.*) Is your answer based on any experience of your own?—No.

20874. You have not tried any comparative experiments?—No, sir.

20875. With your own sewage, with percolating and contact filtration?—No, we have not fall enough; we have often wished to do it; but we have not fall enough to do it.

20876. What you are telling us is what you have got through every filter?—What I am telling you is what we have got through every filter.

20877. But in your answer to 20806*, the third part of the answer, you refer to the deposit of sediment on standing, even on admixture with rain water, as being a peculiarity of percolating filtration. In what cases

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have you found this?—Merely in the cases where iron salts are present; I think it often takes place. A man from Hamburg, Dr. Dunbar, in reading his paper at Glasgow, showed a number of effluents which he had brought over, and they were all percolating effluents, and they nearly all had sediment deposited in them.

20878. You have no experience of your own?—No, sir, but it led me to think that it might be important if that were the case as a rule with them.

20879. There are one or two questions I should like to ask you in regard to trade effluents. You have answered Questions Nos. 20709 and 20710, and I think we gather from those answers that you have had no serious trouble with trade effluents, provided they do not come to you in rushes, if the manufacturers send them down in a regular flow spread over the 24 hours you are quite ready to deal with them?—Yes, sir.

20880. And you tell us that where it is proposed to send a trade effluent into your sewers you make a special arrangement?—Yes, sir.

20881. Have you any general rule to guide you in making that special arrangement; your Corporation has not framed any rules?—(*Mr. Pickles.*) No, we have not; we simply rely on the general Act, and when plans are presented of dye works and extensions we generally get a note put on the plan, and we have no difficulty in getting the owners to carry it out.

20882. What do you ask them to do—settle solids?—Well, as a rule we ask them to put in a tank, a measuring tank, if there is no great quantity of solids present, and then they pay the Corporation so much for treating the sewage, so much per thousand gallons.

20883. You make a charge to them?—We make a charge to them.

20884. But you endeavour as far as possible to get them to send their trade effluent in a regular stream?—Yes, sir.

20885. And not to empty the tanks in rushes?—No. Of course the object is really to keep control of trade effluents.

20886. Have you formed an opinion as to the policy that you should follow; is it better that you should urge upon the manufacturers to treat their own, or do you think it is best that the Corporation should deal with trade effluents *en bloc* subject to certain conditions and charges?—Well, in our case the works are very small, and I do not think it would be advisable to insist upon separate works being put up.

20887. You think it is better for you to do it *en bloc*?—Yes, as far as we are concerned.

20888. Now, in regard to the suspended matter in your sewage, the average of which appears to be very high—119 parts per 100,000. In your answer to Question 20711, I find that. That is a very high average?—(*Mr. Ross.*) Yes.

20889. You have a great deal of suspended matter?—Yes, sir, we have.

20890. On the other hand I notice that in your septic tank effluent you have succeeded in getting a reduction down to 3 to 5 parts per 100,000?—Yes, sir.

20891. It seems exceedingly small, and a very successful result?—Yes.

20892. One is interested to know how you have obtained it. In most other cases we find that septic tank effluents carry away with them a much larger quantity of suspended matter—three or four times as much, and one is interested in knowing by what means you have accomplished this excellent result?—Well, I think one great thing that has helped us towards it is putting in very large detritus tanks. You see we have very large detritus tanks. That takes up such an amount, having each of them to be sludged every third week, so we get rid of a very great deal more of the heavier matter there than in the other tanks; we have very long sills now; the sills extend the whole length of the tank—the outlet sills. I think that makes a great deal of difference, because it prevents not only the formation of currents, but any depth of water over the sill.

20893. It flows over a very thin film?—It flows over a very thin film indeed.

20894. And there is a very small current?—Practically no current.

20895. On the other hand, is there not a discharge in drawing in that way from the top—from the surface of the septic tank?—Oh no, the sill is two feet down below the water level.

20896. The sill is a secondary sill?—Yes, sir.

20897. The sill is not in the tank itself?—(*Mr. Pickles.*) We have really a scum bar, and the bottom of the scum bar is 2 feet below the water level, so that really the sewage has to rise up under the scum bar.

20898. You do not carry away what is floating on the surface?—(*Mr. Ross.*) Oh no, sir.

20899. Then what is the total capacity of your tanks, detritus, septic, and other, in relation to the flow; does it represent one day's flow?—I think 28 hours; without the detritus tanks it is about 28 hours.

20900. And with the detritus tanks?—It would be somewhere about 30 or 31; I could not say exactly.

20901. Then you attribute the fact of your having so little of the suspended matter in your septic tank effluent mainly to the fact that you have large detritus tanks which are frequently emptied and are not allowed to become septic?—Yes, sir.

20902. And that you take the sewage from the septic tanks themselves in a very thin film?—Yes, sir.

20902*. (*Mr. Power.*) Your septic tanks, do you sludge them frequently, as well as the detritus tanks?—The septic tanks will now only be sludged once a year.

20903. Once a year?—I think they will be only; of course we cannot quite say, because we have not run long enough with these new tanks.

20904. And your septic tanks that you have been using formerly you have been sludging every six months, because they have been smaller?—(*Mr. Pickles.*) We have been sludging every six months, but we hope to be able to run 12 months without sludging, but still at present we cannot say definitely whether we shall be able to do so; we may possibly have to sludge every six months still.

20905. And when you sludge the septic tanks you clear them completely, do you?—Completely.

20906. (*Colonel Harding.*) The question Mr. Power puts to you raises a very interesting point. You say you sludge, and you are proposing to sludge at longer intervals; you say you have been sludging at six months, and you hope to reach an interval of 12. When you do sludge you hope to bring everything away altogether. Am I right?—(*Mr. Ross.*) Yes, sir.

20907. Do you not find a new septic tank takes some time to mature and reach full septic conditions?—We have side sluices.

20908. And therefore, after fully emptying a septic tank, you pour into it some septic sludge for the purpose of inoculating it?—Septic liquor rather than septic sludge.

20909. Septic liquor?—As little sludge as possible.

20910. Do you find in that way that on re-starting septic conditions are rapidly reached?—Yes, sir.

20911. Is there any inconvenience in emptying a septic tank at long intervals, say after six months or 12 months, in this respect—that you are having a constantly varying capacity? If you find a certain capacity to be necessary, that capacity of course is being reduced, so that at the end of six months or 12 months it may be the capacity is only half, and therefore the flow is double. Would it not be better—I mean theoretically—instead of emptying at long intervals, to empty very frequently some portion of the sludge out of the septic tank, daily or weekly if it were possible?—In one sense it rather balances itself. Supposing we empty say once a year, and we have 17 tanks; these tanks would be sludged in such rotation that the process of emptying would occur at intervals, so that the capacity of the tanks is very much the same throughout. As we are sludging No. 1, No. 17 has just been sludged; then we turn to No. 1, so that the tanks are always somewhere about the same capacity. Of course, one is at its maximum age and one is practically new, so we are always going round them.

20912. Still in regard to the individual tank, the fact remains that in that case the flow is much greater when the tank is full of sludge?—Yes, sir.

20913. And it might at least be theoretically desirable to maintain a constant capacity by emptying some sludge out frequently?—I think it would be desirable

that we should, if we could, get the sludge pumped without emptying at all; I think it would be the very greatest blessing; the only difficulty is that it so interferes with the work of your presses. You cannot always get sufficient for pressing, and the things do not run as regularly and as economically from a pressing point of view necessarily; they may or may not.

20914. How many tanks have you altogether?—Seventeen, sir.

20915. Instead of your presses depending upon the emptying of one of the 17, it would come to the same thing if 1-17th of each was taken off more frequently, would it not?—It would mean a lot of opening of valves.

20916. But you agree that it would be desirable if it were found practicable?—If it were found practicable, and practical too.

20917. And maintain a constant capacity in the septic tanks?—And, if you could, mix the lime with the sludge.

20918. You have not estimated the digestion?—We have not had gaugings sufficiently accurate to be able to do so.

20919. At least you have formed the opinion that there is not a complete digestion of the suspended matter in the septic tanks?—Oh, no. (*Mr. Pickles.*) I may say with regard to the periodical sludging of the tanks that we did attempt at one time to sludge frequently—that is, without emptying the tank by drawing off the sludge by a sluice at the bottom of the tank; but we found that there was so little sludge came away, and that we got so much sewage with it, that it was not practicable in our case.

20920. The amount of lime that you add to the sludge appears to be very considerable?—(*Mr. Ross.*) Yes, it is; it will not press without it, unfortunately.

20921. Adding that very large quantity of lime to the sludge, you have no trouble at all?—No, sir, no trouble at all; we get very good cake, very solid and firm. (*Mr. Pickles.*) We attribute the success partly to the thorough admixture of the lime with the sludge.

20922. (*Sir William Ramsay.*) I was going to ask you how is the mixture made?—In sludging the tank the sludge is pumped from the tank into the detritus tank, and lime is added at the inlet.

20923. So that it mixes very thoroughly on its way in?—It mixes very thoroughly on its way in; it is really twice mixed. I think we explain that fully in our evidence.

20924. (*Colonel Harding.*) Let me pass on to the question of the contact beds. You tell us that you think the size of the contact beds should be as large as may be conveniently filled in two hours?—Yes, sir; one and a half to two hours.

20925. Would it be an advantage to do it in a shorter period?—One and a half to two hours we have found most convenient, so that we can have the whole flow of sewage on one bed.

20926. But if you had a unit which you could fill in one hour would you not have the advantage of a longer period of rest?—You see the sewage varies, and we keep our larger beds for the larger flow.

20927. Still, the fact remains; would there not be an advantage in having your beds of such size that you may fill them in a shorter time than two hours?—(*Mr. Ross.*) I think it would be good that way if we were able to work more than twice a day; if we were able to fill our beds more than twice a day it would be an advantage, but I think if we fill our beds oftener than twice a day we do not get a good effluent; it seems it will not go.

20928. Because you do not get then sufficient periods of rest?—Yes. There would be an advantage. You see the beds have plenty of rest the way we work them.

20929. Filling only twice a day, what is the length of the cycle 12 hours?—Of course, it is always varying with the weather; in dry weather, such weather as we are having now, it would take 15 hours to fill the beds once.

20930. You mean 15 hours for a cycle?—Fifteen hours for a single cycle, just to fill our contact bed once.

20931. Then there are times when it takes you much longer than two hours to fill a bed?—Yes, there are times when it takes us much longer, but then we should use the small beds in dry weather like this.

20932. It occurs to one if you could fill your beds much more rapidly, in one hour say, it might give you that hour for valuable rest?—I do not think we should materially gain, because filling only twice we have a sufficient period of rest.

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20933. What period of rest do you have?—Well——

20934. Six hours?—Yes, six to eight hours altogether.

20935. And that you think is sufficient?—I think it is sufficient, yes.

20936. So that with two fillings a day you think the unit should be such as may be filled in two hours?—It has worked very well and very conveniently.

20937. Now on the question of the reduction of capacity of contact beds you have given us certain very interesting figures, but what interests me particularly is that you have given us from actual experience of your own the cost of washing the material of the bed?—Yes.

20938. How long now do you think it would be possible to run your contact beds before you reach the necessity of washing out the material; how many years?—(*Mr. Pickles.*) With what has been washed, sir?

20939. No. Suppose you put down a new contact bed; how long do you expect you would be able to run it before you reached the necessity of washing the material?—If the bed is screened and washed in the first instance, as we advise, we think that it would last certainly for seven years.

20940. For seven years?—Yes, if not longer.

20941. (*Mr. Power.*) A primary bed are you speaking of now?—A primary bed, yes, sir.

20942. (*Colonel Harding.*) The secondary bed I suppose will last much longer?—(*Mr. Ross.*) Probably twenty, I think. (*Mr. Pickles.*) We do not propose to wash the secondary beds.

20943. Then you think that will not be necessary?—We think not.

20944. Now down to what point do you propose to reduce the capacity before you wash it?—(*Mr. Ross.*) About 30.

20945. Do you mean 30 per cent.?—No, I mean about 30 gallons per cubic yard.

20946. Well, then, turning to the table that you have given us in connection with your reply to our Question 20783 you there speak to us of contact bed No. 5, and you say that the capacity originally, in June, 1904, was 79 gallons per cubic yard?—Yes, sir.

20947. And that that was reduced down to about 30, I suppose?—49·22, on February 23rd.

20948. Within what time; June, 1904, it was 79; when does it reach 30?—It has not reached 30 at all yet. (*Mr. Pickles.*) The last gauging on February 23rd was 49·22.

20949. Then after nine months it has fallen from 79 to 49?—(*Mr. Ross.*) Yes, sir.

20950. Nevertheless you think before it reaches 30 it will be seven years?—I do, because we have one now that was not screened or washed, that has been working over seven years—seven years last February; that still stands at 24.

20951. That is an instructive and interesting experiment, and we gather from you that under your conditions you may work your primary contact beds for seven years before you reach the necessity of washing, and that when you do wash, from the experience you have actually had it will cost you a shilling per cubic yard?—That is so.

20952. That would point, would it not, to the fact that in many cases it would not be necessary to so completely clarify sewage as to reduce the suspended matter to an absolute minimum?—Oh, quite, yes.

20953. That you can deal upon contact beds with, in your case, you think, 5 grains?—Five parts per 100,000.

20954. Five parts per 100,000 for seven years before needing to wash?—Yes, sir.

20955. That is a very small quantity?—Well, we have had far more than that going in during these experiments, because these new tanks have only just been completed; these new tanks have only been working a few months, so all these are worked with the old tanks.

20956. What quantity of suspended matter?—The suspended matter would be about 15 in this case.

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20957. Fifteen?—Twelve to 15.

20958. Would it not be about the average through the life?—Twelve to 15 throughout all these gaugings.

20959. Are we to take that in your experience—putting 15 parts per 100,000 on to a filter it will last for seven years?—It will last for seven years.

20960. And then it can be washed out at a shilling per cubic yard?—Yes, sir, but the cost is not included in that shilling; the cost of the material which would replace that which is screened out. (*Mr. Ross.*) Well, the cost of carting; the cost of washing and screening the extra material required is included, but the cost of collecting and carting the material down to the works is not included. You see you have a certain amount of waste, when you clean a bed, that has to be replaced.

20961. But you include the primary?—We include the primary, but not the carting.

20962. That would not very materially modify the figure?—(*Mr. Pickles.*) Oh, no, sir. In this table the bed worked continuously, and that is filled twice a day for six months without any periods of rest; we did not allow it any period of rest during that time because we wanted to see really what reduction took place.

20963. (*Mr. Power.*) Have you a fine layer on the surface which you remove from time to time?—(*Mr. Ross.*) No, sir; we have troughs, wooden troughs, and we can sluice those off at the back on to a small land area.

20964. You have not in this respect adopted the Manchester plan?—No, sir.

20965 Was this particular filter never filled more than twice a day, or did it take a chance with the others?—Twice every day whatever happened—it was always filled twice every day during the whole time.

20966. But not oftener?—Not oftener, and never less. (*Mr. Pickles.*) We have a photograph which may be of interest (*handing in photograph*). That just shows the surface of the bed.

20967. (*Colonel Harding.*) What is the age of the eldest bed?—Seven years last February.

20968. At times of storm, when the flow through your septic tank rises to three times the normal, do you not get necessarily a much larger quantity of suspended matter going on to the filters?—(*Mr. Ross.*) Oh, yes, sir; yes, we do.

20969. It is rather curious that in your earlier answers it would seem that in storm times there is very little increase, if any increase, in the suspended matter?—It went up to 9 on the occasion of a four hours' storm.

20970. In your answer to Question 20757?—It went up to 9 as far as I remember, did it not?

20971. In your answer to Question 20757 you tell us that at such times suspended solids averaged from 4 to 9·6 parts per 100,000?—Yes, to 9·6 parts per 100,000. That was taken during a storm; we could not take any number of these for your Commission, because we had not time after getting the questions; but we took the first opportunity of a storm to take a sample, and simply gave these figures; I am afraid they are not the average which I should have liked them to have been if we had had time.

20972. Accounting for the reduction of capacity in contact beds, you give, and very rightly give, great importance to the question of disintegration and consolidation of the material itself?—Yes.

20973. You do not think that the loss of capacity of contact beds is by any means due entirely to the indigestible or undigested matter coming down with the sewage?—Yes, sir.

20974. That is an important factor?—It is an important factor, but not so important as the other; the material is very important.

20975. The consolidation of the material must be due very largely to the fact of material being of uneven size, so that the smaller pieces work in between the larger and so tend to form a solid mass?—In a well-constructed bed I do not think there is so much consolidation as one would expect.

20976. But you say in your answer that consolidation and disintegration account almost entirely for the reduction?—Accounting almost entirely for the reduction: none of our material has been perfect till quite lately. I do not think it is perfect now; it has not been as good as it should have been. We have had a lot of destructor refuse, which was by no means properly burned, and other clinker. Well, you could rather call it ashes than clinker; and I think if you have real clinker, properly screened and washed, that the consolidation will be to a very great extent minimised.

20977. Then the consolidation naturally would be less with material of a fine size to begin with which would not disintegrate?—Yes, sir.

20978. So what you have to aim at is to get material of fine size, and such material as is likely not to disintegrate?—Yes.

20979. You appreciate the great value of that?—Very great. (*Mr. Pickles.*) Yes, sir. That is one reason why we have adopted the washing for new beds.

20980. (*Major-General Carey.*) I want to ask a few questions on Question 20723. Is any difficulty experienced in filtering three times the dry weather flow on the contact beds with septic tank treatment?—(*Mr. Ross.*) No, sir, we can do it easily.

20981. Is that owing to your efficient precipitation in the tanks?—I think we should do it anyway fairly efficiently. When we had a much smaller flow and more suspended matter we still got equally good results, but, of course, we were inclined to fill our beds to a greater extent; I think that is simply about the state of it.

20982. Are the present provisional requirements of the Local Government Boad complied with as to treatment of the storm water over three times the dry weather flow, either in special storm beds or on land, or on both combined?—We treat everything that arrives at the works now; we can treat everything one way or the other.

20983. You are aware of the provisional requirements of the Local Government Board?—Oh, yes; we can do that; we can treat three times the dry weather flow on contact beds.

20984. And over three times?—And over three times we can turn on to big land areas, and we do not run it through the roughing filters as they say, but we store it on these land areas and then run it on to storm beds, where we hold it in contact because we cannot get satisfactory results by running it through a roughing filter at all. We can keep practically all our effluent under the Ribble Joint Committee's standard by treating it in that way.

20985. Then the result of your treatment in this way has been so satisfactory as not to require any modification of the provisional requirements of the Local Government Board?—Well, I see your point. I think it depends very much how you look at it. I do not see why we should not treat three times the dry weather flow, but I do not see why we should take six times the dry weather flow down to the works at all.

20986. That is another point?—Well, that is part of the requirements. That is really where we should differ from them. It hardly comes in there, but it does make the difference why should more than six times in fact come at all any more than six times the whole, the sewage becomes so dilute.

20987. That we will come to presently, but at all events the answer to my question is that with the exception of the number of dilutions, assuming you have to treat so many dilutions, no modification of the requirements is required?—Except as regards method of treatment, which I think would be unsatisfactory. That is, if you are going to pass it through a roughing filter, I do not think you would get a satisfactory effluent.

20988. I think the requirements do not restrict you if put it on land as you are doing here?—We are only holding it up on land; we are not filtering it through land.

20989. Or land in combination with second contacts?—Or land in combination with second contacts; in storage; the land simply comes in as a storage tank; it is not really land treatment.

20990. Then Question 20728, in order to determine the number of dilutions at which storm and sewage may be passed into a stream, do you consider that the same mode of procedure should be adopted as in your reply to Question 20810 as to standards. There you say the standards to be adopted might be arrived at by mutual arrangement between the river authorities and the local authorities; in case of dispute the matter should be referred to the Local Government Board or some speci-

ally constituted authority for arbitration. Would you suggest that the same mode of procedure should be adopted in fixing the number of dilutions. If not, who is to determine the number of dilutions?—I think you would determine from the strength and general conditions of the sewage of the borough how much albuminoid ammonia, dissolved oxygen, and so on, should be present in the final effluent; that would be your fixing the standard; you would fix chemical standards.

20991. I am not on standards now; I am on dilutions; Question 20728?—After how many dilutions you should be allowed to run it into the stream?

20992. Who is to determine the point?—I suppose the rivers authority would be the first people to determine what they consider suitable for the state of their river, and if the chemist in charge advised his corporation, or surveyor in charge advised the Corporation, that the demand was unreasonable, then the matter would be sent for reference.

20993. Practically the same mode of procedure?—Practically the same mode of procedure.

20994. It would be by mutual arrangement?—By mutual arrangement as far as possible.

20995. Between the local authority and the rivers authority?—Yes, as far as possible and when possible. I might say in that respect that I do not think our river authority would raise any objection to it. Under certain circumstances, from what I have heard from Mr. Halliwell, I think he would be rather glad, provided all the first water were taken. That is what I think he objects to mostly, the first runs. Then, provided that were dealt with, that after the storm had continued for some time, and the stream had had time to rise to a definite height, that the remainder should go in.

20996. It could not be left optional with the local authority?—Oh, no.

20997. It would have to be sanctioned by a higher authority; by the Local Government Board, or some other authority?—I do not think we are sufficiently accurate for that, sir.

20998. (*Mr. Power.*) Do you not say that here in your particular circumstances, you think you get the washings of the streets and the yards delivered at the works before you ever get six times the dry weather flow there?—Yes, I think we do.

20999. And as matter of fact you have never dealt with six times the dry weather flow?—No, we cannot get the whole six times; before we get our drains full really it comes to our works. In our case before our drains are full it means such a short flow down to the works, and the town being both paved and hilly the streets are washed in a very short time indeed, and consequently it must arrive at the works before the drains become surcharged.

21000. You get a flood, as it were, at your works before there is any obvious flood in the stream into which your works discharge?—Long before.

21001. (*Major-General Carey.*) Now, Question 20733. On a separate or partially separate system, does not a considerable volume of foul surface water from roads pass untreated into your stream?—(*Mr. Pickles.*) Yes, undoubtedly.

21002. Which is objectionable?—Which is objectionable.

21003. And you have no means of treating it?—No, there are no means of treating it. Of course, we have not found any nuisance to arise from it, but certainly one must admit it is objectionable.

21004. No complaint has been made?—No complaint has been made either from the Rivers Board or from anybody else.

21005. It may be very polluting, of course, the first washings of a road?—I admit that, sir, yes.

21006. Then do you suggest that a separate or partially separate system should be carried out in an existing sewerage system?—Well, we have carried a partially separate system out in an existing system.

21007. In Burnley?—In Burnley, because, owing to the hilly nature of the town and the streets being paved, of course we get a lot of rainfall; the surface water is discharged into the sewers so quickly that the sewers become surcharged, and that causes flooding in the lower part of the town—in fact, not only in the lower part of the town, but in many parts of the town. The Local Government Board sanctioned a scheme for partial surface drainage. That has been mostly carried out, and it has completely cured those parts. At the same time I should not like to advocate the taking out of all the surface water, because we find that it is necessary to turn part of the surface water into the sewers in order to flush them. But from observations that I have made, and from the experience I have had in dealing with this, I think that there would probably be just as much harm done in our case—in fact more harm—in making sewers large enough to take all the surface water than in having them too small, because if you get them too large of course you do not get the self-cleansing velocity.

21008. Now, Question 20753: "How do you think the sludge should be taken out of the tank, and how should it be disposed of?" Does any nuisance attend the operation of removing the sludge from the septic tank?—Not at all, sir.

21009. You have never found that any nuisance has been caused?—We have never found that any nuisance has been caused.

21010. Is the supernatant liquid sent back for treatment or discharged into the stream?—(*Mr. Ross.*) It is pumped back. (*Mr. Pickles.*) From the tank it is pumped back into the inlet channel, and it goes through the tanks again.

21011. That is what I want to know?—After the sewage once arrives at the works we cannot discharge it into the stream until it has gone down to the farm, and either passed through the contact beds or through what we call the storm bed, which is also a second contact bed.

21012. In your reply to Question 20768 you say there is a saving of 60 per cent. effected by contact septic tank treatment as compared with chemical?—That is our experience.

21013. Now, Question 20779: Is 27 to 30 per cent. of the original water capacity of a bed a fair reduction in order to estimate the net average working capacity? You say you take 45 gallons per cubic yard per filling. That works out at 27 per cent. of the original water capacity; for the average working capacity; that is to say, for the reduction caused by the filtering material being put into the bed, and then for loss of capacity afterwards?—Yes, sir.

21014. And that 27 per cent. of course may vary a little, I think from 27 to 32 in other cases; but 27 per cent. in your case is a fair average reduction to establish working capacity?—Yes, we think so. Of course, we know that in many of our beds which we are now washing there has been a much greater reduction. Still, these beds have not been washed or screened, and we think we shall be able to maintain this.

21015. In your reply to Colonel Harding you said that the life of the bed can be maintained by washing the material at certain intervals; is that so?—(*Mr. Ross.*) Yes, sir; and I think, further, that the material that would disintegrate in the bed has actually disintegrated, and that therefore its second life ought to be longer still. That is, the oftener you screen a bed the better the residual material would be.

21016. Would you expect after screening and washing the material to recover the whole of the original capacity?—No, sir, no; what will disintegrate disintegrates, but there will come a point presumably at which the disintegration will be a minimum, where it will reach a minimum, and I fancy when that minimum is reached that the life of the bed will consequently have arrived at its maximum, which is considerably greater than it is under the present circumstances.

21017. Have you estimated the cost of renewing the filtering material for beds per cubic yard?—Entirely throughout, you mean; entirely new material?

21018. Entirely new material?—(*Mr. Pickles.*) Renewing?

21019. Renewing?—It would probably come to about 4s. per cubic yard.

21020. (*Mr. Power.*) For renewing?—This is including the cost of washing; that is the cost of the ashes, collection of ashes and washing and screening, about 4s. per cubic yard.

21021. (*Colonel Harding.*) But we gather from your answer to General Carey that you think it would be far better to wash the old material than to use new?—(*Mr. Ross.*) Much better. (*Mr. Pickles.*) I understand the question is what is the cost.

Mr. G. H. Pickles, and Mr. Raymond Ross, F.I.C., F.C.S.

9 May 1905.

21022. (*Major-General Carey.*) Of renewing?—Of renewing, yes.

21023. If you have to renew the material; if you do not find washing the old material produces the effects you anticipate?—Well, we think the washed material would be far better than the new material.

21024. Have you got any actual experience?—(*Mr. Ross.*) We have got over 12 months of a washed bed.

21025. Of washing?—Yes. We have got over 12 months of a washed bed.

21026. After the bed has been at work?—This bed has now been at work since June 15th; nearly 12 months, you see, it has.

21027. Using washed material?—No, that material has been washed. The bed has been working for some years, but on June 15th it was restarted as a washed bed, and since then it has been working constantly, and has given very satisfactory results, so that we have nearly a year's experience with a bed constructed of washed material—washed and rescreened material.

21028. Do you think you are justified in accepting that the life of a bed can be maintained by screening and removing the material and washing it and putting it back?—And filling in from new material what has been taken out and rejected, yes, sir, I think so.

21029. (*Sir William Ramsay.*) I have only one or two questions to ask. What is a tank?—(*Mr. Pickles.*) A tank is really a cess-pool. At one time in Burnley they were on the tank system, and instead of having the ordinary pail closet, as in most places, there was a wall-tank, or in some places an earthenware tank let into the ground, which was practically a septic tank. It had an overflow connected with the sewer, and this was allowed to be used until it got full, and then, of course, it had to be scooped out, which was a very filthy process. I am very pleased to say there are very few of those left now of either the pail or tank.

21030. Referring to Question 20716, have you made any experiments, Mr. Ross, in the way of getting at the strength of sewage by the quantity of oxygen required to oxidise it? You state here that you prefer a full analysis?—(*Mr. Ross.*) Yes.

21031. But have you made any experiments with reference to the quantity of oxygen required to oxidise it?—We have simply done the three minutes permanganate and four hours permanganate; we do these regularly.

21032. And not shaking up with oxygen?—I have done a considerable number of dissolved oxygen, a very large number, of which the figures, I think, have been supplied to you. I think there were about 270 or 280, and they were taken specially for it, filled into big Winchester quarts, so as to have a large quantity stoppered carefully down, and done as soon as possible both before and after incubation, as suggested by Dr. McGowan, at various periods.

21033. Would you not think that was really sufficient to give you a general idea of the nature of the sewage when you are working with very much the same substance?—I think it would if you are going to fix your standard knowing all about your sewage to begin with, and not going to make it a definite standard for everybody's sewage; I think so.

21034. For your own works it would suit?—For our own works I think it would do; but then you want to know all the circumstances in connection with the works before you could fix the standard which was required.

21035. Naturally, yes, I quite agree. What sort of chemical poisons did you test for?—Well, we know all the trade effluents that go into the works.

21036. There are none?—No, there are none, unless you choose to include gas liquor; of course, that is nothing.

21037. Referring to Question 20723, in which you speak of these land areas, I suppose it is not necessary to puddle those or to make them artificially; the clay is sufficiently non-percolating?—They are underdrained, but it does not matter if they do go through; it would only be land filtration in that case. But so little goes through that it is not worth troubling about.

21038. What is a leap weir?—That is used in connection with a storm overflow. It is really when the quantity of sewage arriving at a manhole attains a certain velocity, it leaps over the channel into the storm overflow, whereas if there is a small flow it has not attained that velocity, and drops down into an intermediate channel which carries it away to the sewer.

21039. Another question on Question 20729. Does the delivery of the surface water into the canal not foul the canal very greatly?—Well, we have had no complaints. There is a lot of suspended matter goes into the canal.

21040. But nothing that makes it smell?—No. (*Mr. Ross.*) I think the canal people are glad to get the water in our part. (*Mr. Pickles.*) And in the canal the water is constantly moving.

21041. The canal in no sense acts as a septic tank?—Oh, no, sir. There are so many locks on the section that the water is admitted at the high portion, and the water in the channel is gradually moving until it gets its outlet at the other end.

21042. Then at the end of Question 20733, I should like to ask is the river sludging at all in its lower reaches; is there any sign of sludging?—Oh, no. Of course, the river throughout the town is paved in the bed. You see they have a very small flow, and rather a quick velocity, and the sides of the river bed—in fact, both rivers—are pitched, sloped to the centre, and then an invert formed. Well, in ordinary weather, the invert, which is about 4 feet 6 inches wide, is quite sufficient to contain all the water coming down.

21043. And that gets scoured out by the water?—That is scoured out.

21044. It has got a smooth bottom practically?—Well, practically; the flow varies so much that instead of allowing it to run in a thin film over the whole width of the stream, about 30 feet wide, in which case there would be no scouring, it is thrown to the centre, and carried by an invert. That is really to prevent a nuisance. (*Mr. Ross.*) It is very hot sometimes, that is one thing. (*Mr. Pickles.*) It is used for condensing water. (*Mr. Ross.*) It is used for condensing water, and gets very hot.

21045. You state, in answer to Question 20794, to use contact beds as streaming filters would be very detrimental to the subsequent working of the bed; is that an answer given from some experience?—To a certain extent it is, sir. We have never been able to obtain any satisfactory results from streaming filters really at all.

21046. May I put it in this way: does it spoil the contact bed, or is it insufficient as a streaming filter?—Well, I was going to answer it in this way: we tried two contact beds, first and second contact, and then we tried constant streaming for a considerable period. We got very poor results indeed. I think we tried it for nine months, with two half-acre beds, and then we converted them back again, and it took a very long time before either of the beds got into anything like condition, two or three times the time that is usually taken to get a bed into condition.

21047. You have answered both parts of my question, both as to the beds and as to the sufficiency of the filter?—Yes, sir.

21048. In answer to Question 20807 you say that a contact bed effluent is superior to an effluent from a percolating filter. It is the second reason I wanted to ask you about. "The organic matter present in it is less putrescible than that present in a percolating filter effluent without subsequent straining, and consequently call is made on the nitric nitrogen." And also you go on to say, "The purification effected in strong sewages by double contact is considerably greater than by a percolating filter." Well, we have heard the answer to No. 3, but about No. 2. How did you manage to make the comparison as regards the putrescibility of the organic matter?—I have not had a great number of these effluents myself, but I have had a certain number, mostly sent at my request by friends, and some few sent in in other ways, and I have always found that with a percolating filter the dissolved oxygen is taken up very much more rapidly than it is with a contact bed effluent to a given point. After that point it does not go on as rapidly, but there seems to be an avidity for oxygen in the first rather short period.

21049. That is precisely what I wanted to find out—how you applied the test?—That is the way; I have tried it by hourly sample in that way, taking it each hour; and I have always found the few experiments, they are not a great number, but the few I have tried

have undoubtedly pointed to the fact that there is an avidity in a percolating filter effluent which is not noticeable in the second contact.

21050. Does it refer really to the liquid portion only?—That I cannot say.

21051. Have you tried it both ways?—No.

21052. It applies to the mixture containing solids?—I have simply taken the effluents as I have received them, without filtration in both cases; I have not filtered them.

21053. Then in reply to Question 20814 you make the statement: "The albuminoid ammonia is still a more useful figure for judging the amount of treatment that the sewage is likely to require, or the amount of unfermented organic matter present in an effluent." Might I ask you how you come to that conclusion?—Well, it seems to me that where you have a concentrated sewage in the ordinary sense—that is to say, a concentrated house sewage—you will have a very high albuminoid ammonia undoubtedly, will you not? Of course, where you have trade effluents they will be shown by the oxygen absorption in three minutes, so that you have got a guide in those two figures as to the amount of house or domestic sewage as against the amount of trade effluents which are probably present in the sewage which you are examining.

21054. But surely you are speaking merely of trade effluents which absorb oxygen readily?—Of course, one cannot say that it is any trade effluent.

21055. Any trade effluent?—Any trade effluent.

21056. In your particular case the trade effluents absorb oxygen readily?—In our particular place there are practically none that do absorb oxygen readily, but, for instance, in Manchester it is the opposite way round. No, that is just where the difference in the sewages would be found out by the difference in the analyses. In our case it is practically a domestic sewage.

BURNLEY.

Appendix to Evidence of Mr. G. H. Pickles *and* Mr. Raymond Ross.

Tables showing average analyses of sewage, septic tank liquor, and filter effluents at Burnley, January, 1903—December, 1904.

PROCESS OF TREATMENT:

Septic Tanks and Double Contact Beds.

BURNLEY.

January, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·15 inches
Maximum daily flow - - — - Rainfall - - - - - 0·98 „
Minimum daily flow - - - — - Rainfall - - - - - 0·00 „

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours		—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average =

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —
Amount of Sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·494	10·290	2·661
Albuminoid Nitrogen	·181	·655	·456
Nitric Nitrogen	* ·3448	·0579	·1271
Chlorine	6·0	9·2	7·4
Oxygen absorbed from $KMnO_4$ in 4 hours	3·830	7·400	6·062
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS—

Number of times Primary Beds were filled during month - - - 62 Average filling - 2
Number of times Secondary Beds were filled during month - - - 62 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·032	2·263	·460
Albuminoid Nitrogen	·028	·120	·055
Nitric Nitrogen	1·1912	·5072	·7524
Chlorine	6·8	9·0	7·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·350	1·339	·702
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

* This exceptionally high figure was due to the presence of some nitre in the sewage which had probably been used for pickling purposes.

April 15th, 1903. *Raymond Ross, F.I.C.*

BURNLEY—*continued.*

February, 1903

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·13 inches

Maximum daily flow - - — - Rainfall - - - - - 0·72 „

Minimum daily flow - - - — - Rainfall - - - - - 0·00 „

Average Analysis of Sewage

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average= .

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - —

Amount of Sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·741	2·056	1·487
Albuminoid Nitrogen	0·197	0·461	0·334
Nitric Nitrogen	0·1006	0·0575	0.0743
Chlorine	6·4	8·8	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	4·998	6·742	6·081
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=20.

FILTERS—

Number of times Primary Beds were filled during month - - - 52. Average filling - 2

Number of times Secondary Beds were filled during month - - - 52. Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·045	0·596	0·242
Albuminoid Nitrogen	0·021	0·098	0·045
Nitric Nitrogen	1·1504	0·5275	0·8539
Chlorine	6·8	8·8	7·8
Oxygen absorbed from $KMnO_4$ in 4 hours	0·455	1·505	0·744
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=20.

REMARKS.—The worst Nitric Nitrogen, both for this month and for the previous month, were from the same bed, which has only been working for a short period.

Raymond Ross, F.I.C.

April 15th, 1903.

BURNLEY—*continued.*

March, 1903.

SEWAGE—

Average daily flow - - — - Rainfall - - - - - 0·20 inches

Maximum daily flow - - — - Rainfall - - - - - 0·96 „

Minimum daily flow - - - — - Rainfall - - - - - 0·00 „

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·699	3·499	1·773
Albuminoid Nitrogen	0·329	1·251	0·619
Nitric Nitrogen	—	—	
Chlorine	4·0	8·9	6·5
Oxygen absorbed from $KMnO_4$ in 4 hours	5·247	9·477	6·296
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 16.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —

Amount of Sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·494	2·223	1·276
Albuminoid Nitrogen	0·172	0·559	0·312
Nitric Nitrogen	0·2204	0·0285	0·1115
Chlorine	4·0	8·8	6·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·164	6·795	4·718
Dissolved Oxygen taken up in 24 hours		—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 22.

FILTERS—

Number of times Primary Beds were filled during month - - - - — Average filling - 2

Number of times Secondary Beds were filled during month - - — Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·028	0·205	0·098
Albuminoid Nitrogen	0·017	0·059	0·039
Nitric Nitrogen	1·6908	0·5636	0·9291
Chlorine	5·6	8·2	6·6
Oxygen absorbed from $KMnO_4$ in 4 hours	0·447	0·950	0 618
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 22.

April 15th, 1903.

Raymond Ross, F.I.C.

April, 1903.

BURNLEY—*continued.*

SEWAGE—

Average daily flow - - - — - Average rainfall - - - - 075 inches

Maximum daily flow - - — - Maximum rainfall - - - ·470 „

Minimum daily flow - - — - Minimum rainfall - - - ·000 „

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·560	3·706	2·710
Albuminoid Nitrogen	·461	1·400	·765
Nitric Nitrogen	—	—	—
Chlorine	7·2	12·0	9·5
Oxygen absorbed from $KMnO_4$ in 4 hours	5·265	15·503	7·591
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - - —

Amount of Sludge dealt with during the month - - - - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·153	3·706	2·278
Albuminoid Nitrogen	·329	·790	·472
Nitric Nitrogen	·2308	·0249	·1347
Chlorine	6·0	13·2	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	4·444	9·333	6·526
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Number of times Primary Beds were filled during month - - - 54 Average filling - 2

Number of times Secondary Beds were filled during month - - - 54 Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·041	1·523	·310
Albuminoid Nitrogen	·029	·131	·056
Nitric Nitrogen	1·9264	·5674	1·1411
Chlorine	6·0	11·2	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·414	1·596	·838
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

REMARKS.—The maximum Albuminoid Nitrogen and Oxygen figures were, in each case, obtained from the newest bed on the works. Leaving this bed out of consideration, the maximum Alb. Nitrogen was 0·079, and the maximum oxygen 1·128.

All the above results are expressed in parts per 100,000.

Raymond Ross, F.I.C.

May 2nd, 1903.

BURNLEY—*continued.*

May, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - ·07 inches

Maximum daily flow - - - — - Rainfall - - - - ·58 „

Minimum daily flow - - - — - Rainfall - - - - - ·00 „

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·153	4·530	2·847
Albuminoid Nitrogen	·461	·988	·794
Nitric Nitrogen	—	—	—
Chlorine	5·6	20·0	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	4·667	9·741	7·845
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 16.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - -

Amount of Sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·762	4·332	2·406
Albuminoid Nitrogen	·263	·790	·546
Nitric Nitrogen	·1735	·0566	·1020
Chlorine	4·0	10·0	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	3·229	9·367	7·029
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 16.

FILTERS—

Number of times Primary Beds were filled during month - - - - 60 Average filling - 2

Number of times Secondary Beds were filled during month - - - 60 Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·076	·905	·309
Albuminoid Nitrogen	·032	·125.	·061
Nitric Nitrogen	1·9662	·4490	1·2278
Chlorine	4·0	10·0	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	·500	1·941	1·000
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 16.

REMARKS.—The average amount of Oxygen absorbed by the final effluent was spoilt by 3 high figures; the nitric Nitrogens were respectively ·449, 1·9662 and 1·1395, so that the purification was after all quite satisfactory

May 31st, 1903. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued*

June, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - 0·054 inches.

Maximum daily flow - - — - Rainfall - - - - - - 0·580 „

Minimum daily flow - - — - Rainfall - - - - - - nil

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·677	4·953	3·384
Albuminoid Nitrogen	·724	1·317	1·035
Nitric Nitrogen	—	—	—
Chlorine	9·6	18·0	13·0
Oxygen absorbed from $KMnO_4$ in 4 hours	5·875	8·715	7·192
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=16.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - —

Amount of Sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·666	5·136	3·218
Albuminoid Nitrogen	·527	·691	·623
Nitric Nitrogen	·2283	nil	·0758
Chlorine	6·4	11·2	9·1
Oxygen absorbed from $KMnO_4$ in 4 hours	3·780	7·721	6·207
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=16.

FILTERS—

Number of times Primary Beds were filled during month - - 60 Average filling - 2.

Number of times Secondary Beds were filled during month - - - 60 Average filling - 2.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·140	·823	·279
Albuminoid Nitrogen	·049	·164	·084
Nitric Nitrogen	2·3973	·6851	1·2845
Chlorine	8·0	11·2	9·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·250	1·902	1·225
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=16.

REMARKS.—During twenty days of this month there was absolutely no rain, and consequently the crude sewage has been very concentrated and more difficult than usual to deal with.

Raymond Ross, F.I.C., F.C.S.

July 7th, 1903.

BURNLEY—*continued.*

July, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·103 inches

Maximum daily flow - - —— - Rainfall - - - - - 0·58 „

Minimum daily flow - - —— - Rainfall - - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·811	4·118	3·253
Albuminoid Nitrogen	·658	1·317	·965
Nitric Nitrogen	—	—	—
Chlorine	8·0	22·0	11·2
Oxygen absorbed from $KMnO_4$ in 4 hours	5·155	9·748	8·232
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 15.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - ——

Amount of Sludge dealt with during the month - - - - - ——

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·647	4·118	3·033
Albuminoid Nitrogen	·527	·856	·677
Nitric Nitrogen	·2232	·0555	·1551
Chlorine	4·4	11·2	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	4·102	8·372	6·145
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average =15.

FILTERS—

Number of times Primary Beds were filled during month - - - - 58 Average filling - 2

Number of times Secondary Beds were filled during month - - - 58 Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·082	1·112	·261
Albuminoid Nitrogen	·033	·112	·078
Nitric Nitrogen	1·7979	·6093	1·0452
Chlorine	7·2	11·2	8·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·265	1·472	·965
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 15.

Raymond Ross, F.I.C. F.C.S.

September 1st, 1903.

BURNLEY—*continued.*

August, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·144 inches.

Maximum daily flow - - — - Rainfall - - - - - 0·71 „

Minimum daily flow - - - — - Rainfall - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·647	3·706	2·828
Albuminoid Nitrogen	·592	·988	·818
Nitric Nitrogen	nil	nil	nil
Chlorine	3·2	20·0	11.4
Oxygen absorbed from $KMnO_4$ in 4 hours	1·000	9·650	8·198
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 15.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —

Amount of Sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·823	4·530	2·580
Albuminoid Nitrogen	·197	·658	·494
Nitric Nitrogen	·1122	·0279	·0685
Chlorine	4·0	12·0	7·4
Oxygen absorbed from $KMnO_4$ in 4 hours	3·122	8·609	5·175
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=15

FILTERS—

Number of times Primary Beds were filled during month - - - - 60. Average filling - 2

Number of times Secondary Beds were filled during month - - - 60. Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·057	1·235	·293
Albuminoid Nitrogen	·033	·118	·057
Nitric Nitrogen	1·3459	·4478	·9120
Chlorine	6·0	10·0	7·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·512	1·389	·912
Dissolved Oxygen taken up in 6 hours at 80° F.	·044	·272	·110
„ „ „ 24 „ at 65° F.	·042	·272	·121

Number of samples analysed for the average = 15.

Raymond Ross, F.I.C., F.C.S.

September 1st, 1903.

BURNLEY—*continued.*

September, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·154 inches
Maximum daily flow - - - — - Rainfall - - - - - 1·22 „
Minimum daily flow - - - — - Rainfall - - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·923	4·118	2·303
Albuminoid Nitrogen	·461	4·942	1·185
Nitric Nitrogen	—	—	—
Chlorine	5·2	13·2	9·5
Oxygen absorbed from $KMnO_4$ in 4 hours	5·250	9·756	8·323
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —
Amount of Sludge dealt with during the month - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·070	5·765	2·303
Albuminoid Nitrogen	·296	·659	·526
Nitric Nitrogen	·1156	nil	·0589
Chlorine	4·0	12·0	7·2
Oxygen absorbed from $KMnO_4$ in 4 hours	3·886	7·846	5·009
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

FILTERS—

Number of times Primary Beds were filled during month - - - 60 Average filling - 2
Number of times Secondary Beds were filled during month - - - 60 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·028	·719	·173
Albuminoid Nitrogen	·021	·112	052
Nitric Nitrogen	1·4623	·5631	1·0077
Chlorine	5·2	10·4	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	·258	1·154	·705
Dissolved Oxygen taken up in 6 hours at 80° F.	·004	·242	·103
„ „ „ 24 „ at 65° F.	·000	·239	·110

Number of samples analysed for the average = 17.

October 1st, 1903. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

October, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - 0·306 inches

Maximum daily flow - - — - Rainfall - - - - - - 1·15 „

Minimum daily flow - - — - Rainfall - - - - - - nil.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·823	3·088	1·784
Albuminoid Nitrogen	·427	1·976	·686
Nitric Nitrogen	—	—	—
Chlorine	5·6	12·0	9·8
Oxygen absorbed from $KMnO_4$ in 4 hours	5·104	9·500	7·653
Dissolved Oxygen taken up in 24 hours	- -	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 12.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —

Amount of Sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·659	2·470	1·482
Albuminoid Nitrogen	·230	·428	·349
Nitric Nitrogen	·2275	nil	·0951
Chlorine	3·2	8·8	6·5
Oxygen absorbed from $KMnO_4$ in 4 hours	3·547	7·215	4·864
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 12.

FILTERS—

Number of times Primary Beds were filled during month - - - - 58 Average filling - 2

Number of times Secondary Beds were filled during month - - - 58 Average filling - 2

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·020	·370	·151
Albuminoid Nitrogen	·019	·065	·037
Nitric Nitrogen	1·2576	·3952	·8800
Chlorine	5·2	8·8	6·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·263	1·600	·513
Dissolved Oxygen taken up in 6 hours at 80° F.	·002	·064	·044
„ „ „ 24 „ at 65° F.	·006	·081	·041

Number of samples analysed for the average = 8.

Raymond Ross, F.I.C., F.C.S.

BURNLEY—*continued.*

November, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - ·074 inches
Maximum daily flow - - — - Rainfall - - - - - - 0·34 „
Minimum daily flow - - - — - Rainfall - - - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·823	3·088	1·874
Albuminoid Nitrogen	·413	1·976	·702
Nitric Nitrogen	—	—	—
Chlorine	4·4	16·0	8·8
Oxygen absorbed from $KMnO_4$ in 4 hours	4·800	9·742	8·214
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

SEPTIC LIQUOR—

Average rate of flow through the tanks - - - - - - - - —
Amount of sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·740	2·667	1·605
Albuminoid Nitrogen	·263	·988	·441
Nitric Nitrogen	·2241	·0577	·1301
Chlorine	4·8	9·6	6·6
Oxygen absorbed from $KMnO_4$ in 4 hours	3·487	8·607	5·883
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS—

Number of times Primary Beds were filled during month - - - 58 Average filling - 2
Number of times Secondary Beds were filled during month - - - 58 Average filling - 2
Estimate of amount of tank liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·020	·412	·111
Albuminoid Nitrogen	·019	·024	·035
Nitric Nitrogen	1·7428	·3436	9919
Chlorine	5·2	8·4	6·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·151	1·291	·524
Dissolved Oxygen taken up in 6 hours at 80° F.	·021	·048	·035
„ „ „ 24 „ at 65° F.	·026	·029	·021

Number of samples analysed for the average = 15.

Raymond, Ross F.I.C., F.C.S.

BURNLEY—*continued.*

December, 1903.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - 0·081 inches
Maximum daily flow - - - — - Rainfall - - - - - 0·80 „
Minimum daily flow - - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·823	3·499	2·045
Albuminoid Nitrogen	0·329	0·988	0·643
Nitric Nitrogen	—	—	—
Chlorine	5·2	13·2	9·1
Oxygen absorbed from $KMnO_4$ in 4 hours	6·513	9·500	8·823
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

SEPTIC LIQUOR—

Average rate of flow through the tanks - - - - - - —
Amount of sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·823	3·091	1·823
Albuminoid Nitrogen	0·230	0·616	0·462
Nitric Nitrogen	0·168	0·056	0·103
Chlorine	4·8	10·0	7·0
Oxygen absorbed from $KMnO_4$ in 4 hours	3·077	8·341	5·924
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

FILTERS—

Number of times Primary Beds were filled during month - - - 60 Average filling - 2
Number of times Secondary Beds were filled during month - - - 60 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·048	0·514	0·187
Albuminoid Nitrogen	0·024	0·079	0·510
Nitric Nitrogen	1·805	0·337	1·078
Chlorine	6·0	10·4	5·7
Oxygen absorbed from $KMnO_4$ in 4 hours	0·250	0·670	1·100
Dissolved Oxygen taken up in 6 hours at 80° F.	·046	·130	·067
„ „ „ 24 „ at 65° F.	·046	·301	·077

Number of samples analysed for the average = 17.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

January, 1904.

SEWAGE—

Average daily flow - — - Rainfall - - - - - 0·12 inches.
Maximum daily flow - — - Rainfall - - - - - 0·54 „
Minimum daily flow - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·474	2·883	1·834
Albuminoid Nitrogen	0·164	0·856	0·551
Nitric Nitrogen	—	—	—
Chlorine	6·4	12·8	9·3
Oxygen absorbed from $KMnO_4$ in 4 hours	6·950	9·750	8·459
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 15.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - —
Amount of Sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·098	2·677	1·575
Albuminoid Nitrogen	0·098	0·659	0·422
Nitric Nitrogen	0·340	0·112	0·177
Chlorine	6·4	8·0	7·3
Oxygen absorbed from $KMnO_4$ in 4 hours	2·308	7·375	5·717
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 15.

FILTERS—

Number of times Primary Beds were filled during month - - - 59 Average filling - 2
Number of times Secondary Beds were filled during month - - - 59 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·012	1·235	0·323
Albuminoid Nitrogen	0·021	0·098	0·050
Nitric Nitrogen	1·591	0·343	1·024
Chlorine	5·6	8·0	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	0·517	1·111	0·686
Dissolved Oxygen taken up in 6 hours at 80° F.	·037	·199	·092
„ „ „ 24 „ at 65° F.	·006	·111	·066

Number of samples analysed for the average = 15.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

February, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·13 inches
Maximum daily flow - - - — - Rainfall - - - - - 0·78 „
Minimum daily flow - - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·823	3·089	1·657
Albuminoid Nitrogen	0·395	0·790	0·566
Nitric Nitrogen	—	—	—
Chlorine	8·0	11·2	9·3
Oxygen absorbed from $KMnO_4$ in 4 hours	7·325	9·747	8·439
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for average=12.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - -
Amount of Sludge dealt with during the month - - - - -

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·494	3·089	1·506
Albuminoid Nitrogen	0·197	0·658	0·385
Nitric Nitrogen	0·347	0·113	0·230
Chlorine	6·4	8·0	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	3·875	8·405	6·302
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average=12.

FILTERS—

Number of times Primary Beds were filled during month - - - 56 Average filling - 2
Number of times Secondary Beds were filled during month - - - 56 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·024	0·576	0·246
Albuminoid Nitrogen	0·017	0·085	0·046
Nitric Nitrogen	1·396	0·456	0·971
Chlorine	6·4	8·0	7·4
Oxygen absorbed from $KMnO_4$ in 4 hours	0·125	1·175	0·604
Dissolved Oxygen taken up in 6 hours at 80° F.	·031	·063	·059
„ „ „ 24 „ at 65° F.	·032	·099	·057

Number of samples analysed for the average=12.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

March, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - - ·05 inches
Maximum daily flow - - — - Rainfall - - - - - - - ·27 „
Minimum daily flow - - — - Rainfall - - - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·030	3·089	2·249
Albuminoid Nitrogen	·339	0·987	0·703
Nitric Nitrogen	—	—	—
Chlorine	7·2	10·4	9·3
Oxygen absorbed from $KMnO_4$ in 4 hours	5·950	9·444	7·998
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 16.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —
Amount of Sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·823	3·089	2·075
Albuminoid Nitrogen	0·263	0·659	0·527
Nitric Nitrogen	0·239	0 111	0·205
Chlorine	7·2	9·6	7·9
Oxygen absorbed from $KMnO_4$ in 4 hours	4·125	8 750	6·932
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 16.

FILTERS—

Number of times Primary Beds were filled during month - - - 60 Average filling - 2
Number of times Secondary Beds were filled during month - - - 60 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·082	1·647	0·439
Albuminoid Nitrogen	0·034	0·197	0·065
Nitric Nitrogen	1·895	0·465	1·179
Chlorine	7·2	8·8	7 9
Oxygen absorbed from $KMnO_4$ in 4 hours	0·250	2·000	0·839
Disolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 16.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

April, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - ·04 inches
Maximum daily flow - - - — - Rainfall - - - - - 0·17 „
Minimum daily flow - - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·441	3·500	2·714
Albuminoid Nitrogen	·560	1·317	·788
Nitric Nitrogen	—	—	—
Chlorine	8·8	11·2	9·9
Oxygen absorbed from $KMnO_4$ in 4 hours	7·727	9·792	8·517
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 13.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - —
Amount of Sludge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·441	3·294	2·539
Albuminoid Nitrogen	·263	1·008	·595
Nitric Nitrogen	·229	·112	·136
Chlorine	7·2	9·6	8·3
Oxygen absorbed from $KMnO_4$ in 4 hours	6·477	8·536	8·195
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 13.

FILTERS—

Number of times Primary Beds were filled during month - - - 59 Average filling - 2
Number of times Secondary Beds were filled during month - - - 59 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·041	2·058	0·467
Albuminoid Nitrogen	0·003	0·082	0·074
Nitric Nitrogen	1·372	0·673	1·154
Chlorine	7·2	9·6	8·3
Oxygen absorbed from $KMnO_4$ in 4 hours	·256	1·281	·504
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 13.

February 27th, 1905. *Ramond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

SEWAGE— May, 1904.

Average daily flow - - - — - Rainfall - - - - - ·09 inches
Maximum daily flow - - - — - Rainfall - - - - - ·40 „
Minimum daily flow - - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·647	4·941	3·338
Albuminoid Nitrogen	·658	1·976	·999
Nitric Nitrogen	—	—	—
Chlorine	8·8	12·8	10·3
Oxygen absorbed from $KMnO_4$ in 4 hours	9·307	9·872	9·588
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - - —
Amount of Sludge dealt with during the month - - - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·235	4·117	2·964
Albuminoid Nitrogen	·266	1·054	·642
Nitric Nitrogen	·231	Nil.	·115
Chlorine	8·0	10·2	8·7
Oxygen absorbed from $KMnO_4$ in 4 hours	5·384	8·250	7·093
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

FILTERS—

Number of times Primary Beds were filled during month - - - 60 Average filling - 2
Number of times Secondary Beds were filled during month - - - 60 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst	Average.
Ammoniacal Nitrogen	·164	2·058	·392
Albuminoid Nitrogen	·046	0·133	·076
Nitric Nitrogen	1·923	·577	1·227
Chlorine	7·2	11·2	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·410	1·266	·873
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

June, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - ·03 inches.
Maximum daily flow - - — - Rainfall - - - - - 35 „
Maximum daily flow - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·058	5·146	3·212
Albuminoid Nitrogen	·327	2·964	1·045
Nitric Nitrogen	—	—	—
Chlorine	8·0	13·6	10·1
Oxygen absorbed from $KMnO_4$ in four hours	7·625	9·875	9·077
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - —
Amount of Sludge dealt with during the month - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·647	4·117	3·321
Albuminoid Nitrogen	·395	1·494	·577
Nitric Nitrogen	·114	·056	·108
Chlorine	8·0	9·6	9·0
Oxygen absorbed from $KMnO_4$ in 4 hours	5·375	8·825	7·080
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Number of times Primary Beds were filled during month - - - - 59 Average filling - 2
Number of times Secondary Beds were filled during month - - - 59 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·123	1·647	·589
Albuminoid Nitrogen	·039	·149	·091
Nitric Nitrogen	1·946	·230	·990
Chlorine	7·2	10·8	8·8
Oxygen absorbed from $KMnO_4$ in 4 hours	·250	3·000	1·159
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued*

July, 1904.

SEWAGE—

Average daily flow - - - — Rainfall - - - - - ·03 inches
Maximum daily flow - - — - Rainfall - - - - - ·17 „
Minimum daily flow - - — Rainfall - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	3·087	5·353	4·379
Albuminoid Nitrogen	·527	2·108	1·127
Nitric Nitrogen	—	—	—
Chlorine	10·4	22·0	12·5
Oxygen absorbed from $KMnO_4$ in 4 hours	7·122	9·450	8·208
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 15.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - —
Amount of Sledge dealt with during the month - - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·058	4·941	3·912
Albuminoid Nitrogen	·395	·856	·600
Nitric Nitrogen	·114	Nil.	096
Chlorine	8·8	11·2	10·3
Oxygen absorbed from $KMnO_4$ in 4 hours	5·122	8·585	6·664
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 15.

FILTERS—

Number of times Primary Beds were filled during month - - - - 59 Average filling - 2
Number of times Secondary Beds were filled during month - - - 59 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·164	1·543	·691
Albuminoid Nitrogen	·066	·148	·093
Nitric Nitrogen	1·983	·571	1·141
Chlorine	8·8	12·0	9·8
Oxygen absorbed from $KMnO_4$ in 4 hours	·538	1·129	·898
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 15.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

August, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - ·15 inches
Maximum daily flow - - — - Rainfall - - - - - - 1·04 „
Minimum daily flow - - - — - Rainfall - - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	2·058	4·558	3·006
Albuminoid Nitrogen - - - - - - - - -	·263	1·647	·993
Nitric Nitrogen - - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - - -	4·0	18·0	10·5
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	5·555	15·366	9·347
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—

Number of samples analysed for the average = 16.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - —
Amount of Sludge dealt with during the month - - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	1·441	4·117	2·887
Albuminoid Nitrogen - - - - - - - - -	·263	·593	·429
Nitric Nitrogen - - - - - - - - - -	·114	Nil.	·075
Chlorine - - - - - - - - - - -	5·2	10·0	7·9
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	3·750	6·800	4·716
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—

Number of samples analysed for the average = 16.

FILTERS—

Number of times Primary Beds were filled during month - - - 60 Average filling - 2
Number of times Secondary Beds were filled during month - - - 60 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	·140	1·934	·451
Albuminoid Nitrogen - - - - - - - - -	·026	·099	·071
Nitric Nitrogen - - - - - - - - - -	2·053	·678	1·323
Chlorine - - - - - - - - - - -	6·0	10·0	8·3
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	·390	1·250	·838
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—

Number of samples analysed for the average = 16.

February 27th, 1905.

Raymond Ross, F.I.C., F.C.S.

BURNLEY—*continued.*

September, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·04 inches
Maximum daily flow - - — - Rainfall - - - - - 0·35 „
Minimum daily flow - - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·882	6·176	4·807
Albuminoid Nitrogen	·823	4·776	1·853
Nitric Nitrogen	—	—	—
Chlorine	10·4	21·2	12·8
Oxygen absorbed from $KMnO_4$ in 4 hours	7·500	23·722	12·710
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

SEPTIC LIQUOR—

Average rate of flow through the tanks - - - - - - - - —
Amount of Sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·058	5·764	3·864
Albuminoid Nitrogen	·263	·659	·497
Nitric Nitrogen	·115	—	·069
Chlorine	8·0	11·6	9·6
Oxygen absorbed from $KMnO_4$ in 4 hours	4·683	7·111	5·376
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

FILTERS—

Number of times Primary Beds were filled during the month - - - 58 Average filling - 2
Number of times Secondary Beds were filled during the month - - - 58 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·123	2·058	·542
Albuminoid Nitrogen	·044	·178	·090
Nitric Nitrogen	2·480	1·110	1·551
Chlorine	8·0	11·2	9·8
Oxygen absorbed from $KMnO_4$ in 4 hours	·439	1·636	1·057
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 17.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

October, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - 0·08 inches
Maximum daily flow - - - — - Rainfall - - - - - 0·56 „
Minimum daily flow - - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·470	6·110	4·269
Albuminoid Nitrogen	·658	1·647	1·365
Nitric Nitrogen	—	—	—
Chlorine	8·8	26·0	14·2
Oxygen absorbed from $KMnO_4$ in 4 hours	9·634	17·400	13·866
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - —
Amount of Sludge dealt with during the month - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·647	5·764	3·884
Albuminoid Nitrogen	·494	·823	·585
Nitric Nitrogen	·115	Nil.	·087
Chlorine	5·2	26·0	12·7
Oxygen absorbed from $KMnO_4$ in 4 hours	5·450	19·480	8·1
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Number of times Primary Beds were filled during month - - - 60 Average filling - 2
Number of times Secondary Beds were filled during month - - - 60 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·123	2·470	·697
Albuminoid Nitrogen	·039	·132	·101
Nitric Nitrogen	2·181	·576	1·474
Chlorine	7·2	22·8	11·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·400	1·593	1·259
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

November, 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - ·10 inches
Maximum daily flow - - — - Rainfall - - - - - 1·30 ,,
Minimum daily flow - - — - Rainfall - - - - - Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·235	6·176	3·254
Albuminoid Nitrogen	·576	2·834	1·330
Nitric Nitrogen	—	—	—
Chlorine	5·2	23·6	12·7
Oxygen absorbed from $KMnO_4$ in 4 hours	7·297	18·400	12·851
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 16.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - —
Amount of Sludge dealt with during the month - - - —

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·412	6·588	3·784
Albuminoid Nitrogen	·184	1·153	·523
Nitric Nitrogen	·341	·114	·126
Chlorine	5·2	14·0	10·8
Oxygen absorbed from $KMnO_4$ in 4 hours	1·513	10·000	7·764
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 16.

FILTERS—

Number of times Primary Beds were filled during month - - - 59 Average filling - 2
Number of times Secondary Beds were filled during month - - - 59 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - —

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·144	1·316	·701
Albuminoid Nitrogen	·064	·165	·118
Nitric Nitrogen	2·905	·592	1·333
Chlorine	6·8	12·8	10·3
Oxygen absorbed from $KMnO_4$ in 4 hours	·591	1·870	1·205
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 16.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY—*continued.*

December 1904.

SEWAGE—

Average daily flow - - - — - Rainfall - - - - - - 0·09 inches
Maximum daily flow - - — - Rainfall - - - - - - 0·59 „
Minimum daily flow - - - — - Rainfall - - - - - - Nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·235	3·706	2·242
Albuminoid Nitrogen	·461	1·647	·898
Nitric Nitrogen	—	—	—
Chlorine	6·4	12·0	10·2
Oxygen absorbed from $KMnO_4$ in 4 hours	8·000	16·000	13·484
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

SEPTIC LIQUOR—

Average rate of flow through the Tanks - - - - - - - —
Amount of Sludge dealt with during the month - - - - - - —

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·235	3·706	2·496
Albuminoid Nitrogen	·441	1·318	·535
Nitric Nitrogen	·118	Nil	·099
Chlorine	6·0	11·6	8·7
Oxygen absorbed from $KMnO_4$ in 4 hours	4·708	9·545	6·968
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Number of times Primary Beds were filled during month - - - - 61 Average filling - 2
Number of times Secondary Beds were filled during month - - - - 61 Average filling - 2
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·065	1·235	·602
Albuminoid Nitrogen	·025	·112	·089
Nitric Nitrogen	1·366	·469	·881
Chlorine	6·0	10·0	8·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·506	2·545	1·113
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 18.

February 27th, 1905. *Raymond Ross, F.I.C., F.C.S.*

BURNLEY CORPORATION DUCKPITS AND

Dissolved Oxygen in Parts

Date, 1904.	No. of Bed.	Effluent + Two volumes of Tap Water.				
		Immediate Tritation.	Incubated for 6 hours at 80° F.	Incubated for 24 hours at 65° F.	Immediate Tritation.	Incubated for 6 hours at 80° F.
3 August	19	0·81	0·79	0·81	0·58	0 45
4 August	16	0·73	0·48	0·28	0·23	Nil.
5 August	17	0·77	0·72	0·71	0·50	0·38
10 August	22	0·74	0·74	0·72	0·30	0·26
11 August	23	0·78	0·71	0·71	0·35	0·21
12 August	14	0·70	0·63	0·63	0·23	0·07
17 August	15	0·80	0·78	0·74	0·28	0·27
18 August	19	0·78	0·78	0·78	0·32	0·29
19 August	16	0·76	0·76	0·75	0·21	0·11
24 August	17	0·71	0·69	0·69	0·29	0·18
25 August	22	0·71	0·70	0·63	0·31	0·19
26 August	23	0·74	0·65	0·66	0·38	0·17
31 August	19	0·92	0·85	0·92	0·62	0·57
1 September	14	0·79	0·75	0·67	0 31	0·07
2 September	15	0·82	0·69	0·73	0·29	0·14
8 September	16	0·94	0·80	0·64	0·43	0 30
9 September	16	0·92	0·86	0·85	0·56	0·51
14 September	22	0 95	0·92	0·91	0·46	0·42
15 September	19	1·06	0 89	0·90	0·55	0·50
16 September	14	0 90	0·85	0·89	0·41	0·32
21 September	15	1·07	0·83	0·88	0·43	0·43
22 September	16	0·90	0·77	0·67	0·29	0·14
23 September	17	0·82	0·76	0·76	0·39	0·27
28 September	22	0·88	0·55	0·82	0·42	0·22
29 September	19	0·86	0·77	0·85	0·55	0·52
30 September	14	0·89	0·80	0·89	0·62	0·54
5 October	15	0·72	0·69	0·68	0·52	0·42
6 October	16	0·80	—	0·74	0·53	—
7 October	17	0·80	0·74	0·63	0·61	0·57
12 October	22	0·84	0·75	0·82	0·54	0 50
13 October	19	0·86	0·82	0·82	0·72	0·72
14 October	14	0·88	0·84	0·88	0.66	0·63
19 October	15	0·86	0·82	0·80	0·63	0·57
20 October	16	0 88	0·82	0·82	0·56	0·56
21 October	17	0·90	0·84	0·89	0·60	0·49
26 October	22	0 89	0·87	0 86	0·74	0·68
27 October	19	0·87	0·86	0·87	0·72	0.68
2 November	15	0·86	0·84	0·84	0·59	0·55

WOOD END SEWAGE DISPOSAL WORKS.

PER 100,000 BY WEIGHT.

Analysis of Second Contact Effluent.

Incubated for 24 hours at 65° F.	Free Ammonia.	Albuminoid Ammonia.	Nitric Nitrogen.	Chlorine.	3 minutes' Oxygen Test.	4 hours' Oxygen Test.
0·45	·200	·020	813	8·0	·388	·849
Nil.	·225	·032	1·009	8·0	·271	1·160
0·36	·150	·052	7·908	9·2	·297	1·339
0·26	·250	·048	1·0242	10·0	·488	·976
0·11	·230	·072	·6696	10·0	·650	1 075
0·00	·550	·096	·8370	9·2	·600	1·2 0
0·23	·400	·080	·7869	8·0	·413	·611
0·29	·200	·064	1·0025	8·0	·122	·853
0·11	·100	·040	2·2436	7 2	·275	·675
0·20	·375	·096	·5674	8·0	Nil.	·200
0·12	·120	·052	1·0305	8·0	·253	·456
0·18	·350	·096	·5636	8·0	·650	1·250
0·57	·035	·030	·8964	6·8	Nil.	·500
0·08	·250	·092	1·1216	8·0	·425	1·125
0·08	·350	·088	·6790	8·8	·350	·875
0·20	·250	·104	1·0221	6·8	·238	1·357
0·47	—	—	1·2365	6·8	·155	·414
0·43	·200	·040	·9309	6·0	Nil.	·649
0·48	·080	·032	1·2714	7·2	Nil.	·649
0·32	·150	·064	1·3870	6·0	·131	·649
0·43	·450	·080	·5674	8·8	Nil.	·633
0·07	·250	·080	·8536	8·8	·609	·975
0·25	·250	·080	·7316	8·8	·285	·701
0·38	·320	·080	·8956	10·0	·222	·979
0·55	·250	·064	1·4463	8·8	·253	·455
0·57	·100	·040	1·2276	8·0	·125	·500
0·43	·325	·064	1·1072	10·0	·128	·590
0·48	·100	·040	·9985	7·2	·300	·625
0·57	·025	·015	1·2544	6·0	·247	·444
0·48	·080	·032	1·7910	8·4	Nil.	·400
0·72	·035	·024	1·0075	5·6	Nil.	·513
0·64	·060	·024	1·2516	5·2	·123	·513
0·55	·220	·056	0·5702	5·2	·129	·390
0·46	·040	·030	0·5702	6·0	Nil.	·260
0·59	·085	·048	1·2516	6·0	·256	·384
0·70	·040	·021	1·2349	6·0	Nil.	·128
0·72	.035	·024	1·1227	6·8	Nil.	Nil.
0·57	·250	·040	·7018	8·0	·126	·506

RAYMOND ROSS, F.I.C., F.C.S.

SEVENTY-THIRD DAY.

Wednesday, 10th May, 1905.

PRESENT.

The Right Honourable the Earl of Iddesleigh (*Chairman*), *presiding*.
Sir William Ramsay, K.C.B., F.R.S.
Major-General Constantine Phipps Carey, C.B., R.E.
Mr. W. H. Power, C.B., F.R.S.
Colonel T. W. Harding, J.P.
Mr. T. J. Stafford, F.R.C.S.I.
Mr. F. J. Willis (*Secretary*).

ALSO PRESENT.

Dr. A. C. Houston, M.D.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. Joshua Bolton, Manager of the Heywood Borough Sewage Purification Works, called in; and Examined.

Mr. Joshua Bolton.
10 May 1905.

21057. (*Chairman.*) You are Mr. Joshua Bolton, Manager of the Sewage Purification Works belonging to the Corporation of Heywood, and you have come before us to-day to give the results of your experience of sewage disposal works?—Yes.

21058. What is your general system of treatment of sewage at Heywood?—Chemical precipitation and subsequent single contact.

21059. What is the population draining to the Heywood works?—23,500.

21060. What is the system of drainage—that is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent?—Combined; all storm water enters the sewers.

21061. Is there any infiltration of subsoil water into the sewers?—Yes. About 109,000 gallons per 24 hours in dry weather.

21062. What is the water supply per head, and from what source does it come?—The water supply is 20 gallons per head, and is collected on local hills.

21063. Is it hard or soft water?—It is soft water; total hardness 5°, permanent 4·6°, temporary 0·4°.

21064. What is the drainage area of the part of the town which is sewered?—525 acres.

21065. What proportion of the population use pail closets or middens, and what proportion use water-closets?—Pails, 3,783; middens, 6,039; total; 9,822 Fresh water closets, 1,211; slop water, 12,467; total, 13,678.

21066. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather, in winter and in summer?—Yes. The average of the winter of 1903 dry days was 774,510 gallons per 24 hours. The average of the summer of 1903 dry days was 629,172 gallons per 24 hours, a difference of 145,338 gallons per 24 hours.

21067. What is the maximum dry weather rate of flow, and at what hour does this occur?—The maximum dry weather flow is about 1,098,000 gallons per 24 hours, and takes place between the hours of 10 a.m. and 5 p.m.

21068. What is the minimum dry weather rate of flow, and at what hour does it occur?—The minimum dry weather flow is 324,000 gallons per 24 hours, and takes place between 1 a.m. and 6 a.m.

21069. What is the maximum wet weather rate of flow which you have observed coming to your works, and during how many hours has this continued?—Our storm overflows are set to deliver 4,200,000 gallons per 24 hours. This rate has been recorded continuously for 11 hours.

21070. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation?—No storm overflows are fixed on the sewers. The whole of the storm water is conveyed to the entrance to the sewage works, where a half-inch primary screen is fixed, cleaned by revolving rakes. The grosser solids are thus arrested before the storm water passes over the storm overflows to the river. This storm overflow comes into operation at six times the average dry weather flow, *i.e.*, 4,200,000 gallons.

21071. What is the largest number of gallons of sewage which have passed the storm overflow and come to your works in 24 hours?—3,573,000 gallons.

21072. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—Yes; 362,008,000 gallons.

21073. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year, and the volume which passes over your overflows?—The volume which comes to the works is 394,025,000 gallons. No continuous gaugings have been taken as to the amount of sewage passing over the storm overflows. Gaugings during very heavy rain have registered at the rate of 30,000,000 gallons per 24 hours. These flows have not been of long duration. The rainfall on the drainage area, plus the water supply, equals 533,558,000 gallons; deduct 394,025,000 gallons delivered at the sewage works, leaves 139,533,000 gallons as having passed to the river.

21074. Does the infiltration of subsoil water into your sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—It does not occur regularly, but differs according to the state of the seasons and weather. The only means I have of gauging this inflow is by comparing the low night flows in summer and winter. From these figures I get an excess in winter over summer of 99,000 gallons per 24 hours.

21075. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of these effluents?—About 70,000 gallons per day. This consists of brewery, dye, tannery, and fellmongers' waste. No analyses have been obtained owing to the manufacturers having free access to the sewers.

21076. Has your authority framed any rules as to the reception of trade effluents into the sewers?—No.

21077. Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise? If so, would you kindly tell us what your difficulties are?—Trade effluents of the nature we get do not interfere materially with the treatment when delivered in a regular stream. In the case of one or two manufacturers their wastes are turned into the sewers at intervals in large volumes. There is then a difficulty in treatment owing to the precipitant not being regulated to the increased strength and volume of the sewage.

21078. In dry weather what is the average amount of suspended matter in the sewage, and what are the highest and lowest figures in parts per 100,000?—The average amount of suspended matter in dry weather is 29 parts per 100,000. The maximum amount is about 46 parts per 100,000; during the night it has fallen

as low as 6 parts per 100,000. These figures do not include the screen refuse and the grit, etc., which settles in the "catch pits."

21079. What is the physical character of these solids?—The solids consist of large numbers of cotton fibres, fat, insoluble soaps, small particles of paper, excreta, etc.

21080. Can you give average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—Yes, the analyses are as follows:—

	1903.		1904.	
	Summer.	Winter.	Summer.	Winter.
Oxygen absorbed 4 hours' test	8·32	6·73	8·66	7·86
Ammoniacal nitrogen	3·23	3·19	3·52	3·51
Albuminoid nitrogen	·63	·86	1·03	·80
Chlorine	7·9	6·4	8·3	7·2

21081. Is it a "strong" sewage, and, if so, what characterises its strength?—From the foregoing analyses I consider the sewage to be a fairly strong domestic sewage. I judge the strength of the sewage on the albuminoid nitrogen and the oxygen absorbed figures.

21082. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—The sewage varies considerably from hour to hour, as shown by the Diagram No. 1 on the oxygen absorbed test. We do not get a tank effluent which varies in the same degree. Taking the flow from day to day there is a varying strength on various days, Mondays and Tuesdays being the worst; this fluctuation is noticeable also in the subsequent effluents, as shown in the Diagram No. 2. (*See* Diagrams at end of Mr. Bolton's evidence.)

21083. How do you think "strength" of sewage, as affecting purification, is best expressed or measured?—In my opinion the strength of the sewage is given best on the albuminoid nitrogen and oxygen absorbed figures.

21084. Have you any information as to the bacteriological condition of the sewage?—No.

21085. Are there any chemical poisons in the sewage?—No.

21086. Is the sewage always alkaline?—Yes.

21087. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—The suspended solids are greatly increased in times of storm. The following figures were obtained during heavy rain lasting four hours:—

First rushes	238	parts per 100,000
After one hour	110	,, ,, ,,
After two hours	69	,, ,, ,,
After three hours	50	,, ,, ,,
After four hours	38	,, ,, ,,
After five hours	33	,, ,, ,,
After six hours	28	,, ,, ,,
After seven hours	18	,, ,, ,,

21088. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—Thirty-five years. There are a number of places where the sewers have sunk, and accumulations do occur, and are washed to the sewage works in times of storm.

21089. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this by analyses of the liquid portion in dry weather and in storm times?—The liquid part of the sewage for the first two hours is very foul. If the storm is of long duration the liquid gradually gets weaker. The following figures show analyses of (a) the liquid part of the sewage, (b) the liquid part after two hours storm flow, and (c) after five hours storm flow:—

	(a)	(b)	(c)
Oxygen absorbed (four hours' test)	5·80	3·20	1·62
Ammoniacal nitrogen	1·65	2·70	1·19
Albuminoid nitrogen	·39	·24	·10
Chlorine	8·3	7·4	4·9

21090. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely-increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm? I should be glad if you would state your views fully on this question and if you would also tell the Commission what number of dilutions you think it practicable to treat in one or another way?—At Heywood we have endeavoured to treat our storm water in accordance with the requirements of the Local Government Board. Three times the dry weather flow being passed through the tanks, and from three to six times the flow dealt with on special storm filters. In my opinion this method is not the most satisfactory, either to the local authorities or to the conditions of the rivers. I find that admitting three times the dry weather flow to the tanks brings about a serious condition in the tank effluent. Not only is the effluent at first composed of partly settled sewage, but the sludge in the tanks is disturbed, and in the course of two or three hours after the storm flow has reached the works the tank effluent is in a worse condition than the in-coming sewage. The effect of passing this effluent on the filters is almost ruinous. The whole surface of the filters (contact beds) becomes coated with a layer of fine mud, which requires removing at considerable expense before the ordinary volume can be passed on the bed, the sludge interfering with the free passage of the liquid. In our storm filters provision is made for treating 500 gallons per square yard. There is a cast-iron distributing trough down the centre of the beds. When the storm water reaches the troughs it flows over the sides and down through the cinders to the effluent drains until the surface becomes choked. The water then flows over the choked surface to the free portions of the bed, thus gradually choking the whole areas of the beds. The surface of our beds become choked at the rate of 355 square yards per month when dealing with a storm flow on a dry weather flow of 500,000 gallons per day. The flow through storm filters is extremely rapid, owing to not being evenly distributed over the bed. The following are

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average analyses after the first rushes of a storm: (a) Storm sewage two and a-half hours after storm commenced, (b) same sewage after being settled two hours in a tank, (c) storm filter effluent 20 minutes after sampling (a):—

	(a)	(b)	(c)
Oxygen absorbed (four hours' test) - -	5·00	3·20	3·66
Ammonical nitrogen -	1·84	1·55	1·64
Albuminoid nitrogen -	·56	·37	·56
Chlorine - - -	4·8	4·5	4·6
Suspended solids - -	61	16	23

The two hours settlement gave a better result than the storm filters. I consider a good plan of dealing with storm water would be to pass only twice the average dry weather flow through the ordinary tanks, and from two to six times through special settling tanks having a capacity equal to a six hours' flow. I think a portion of the effluent from these tanks could be passed through percolating filters more rapidly without doing damage than could an effluent from the ordinary dry weather tanks when worked at the rate of three times the dry weather flow. Though the increase in volume should be obtained by decreasing the intervals of rest between the discharges rather than by turning it on in excessive volumes. A great saving could be effected by collecting the sludge from the storm water in tanks, and dealing with it along with the other sludge rather than by collecting a portion of it on storm filters and skimming it off by manual labour.

21091. What shape and size are your storm overflows?—Our first overflow is in the form of a leap weir 8ft. long. A half-inch primary screen is fixed in front of the overflow so that the grosser solids do not go to the river. This does not work very satisfactorily. Another overflow is fixed on the weir principle, which passes any excess (which has passed the leap weir) on to the river. These sills are 4ft. 6in. long.

21092. Would it be possible to have a standard form of overflow, and how would you fix the point at which overflows should be allowed to come into operation?—I think a good form for a standard overflow would be one with a long sill and two or three baffle plates fixed at right angles to the sill. Whatever number of dilutions are decided on, the sill and baffle plates should be fixed so that the baffle plates would turn the excess water either to the river or storm tanks as the case may be. This arrangement could be easily arranged for either fixed or movable overflows.

21093. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—I do not see how it would be possible to arrange a fixed overflow to suit varying conditions. The first rushes of storm water in a hilly district bring down large quantities of solid impurities which ought to be intercepted. However, if the storm overflows were fixed high to intercept it, a large volume of weak sewage would unnecessarily be passed on to the works, and would probably push out the partly-settled strong storm water at the other end.

21094. Should storm overflows be fixed or movable?—If storm overflows were movable some of the difficulties would be overcome. The possibility of misuse would be a strong factor against movable overflows. Under sound and reliable control a movable overflow would be most satisfactory for general conditions.

21095. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case?—It may be possible in towns on a tidal river to allow the storm overflows to come into operation at a less number of dilutions than inland towns. I do not think there are any rivers which do not suffer from the first rushes of storm water, though naturally the tidal rivers will not suffer to the same extent as the inland rivers. My experience on a river of 30 times the volume of the inflowing sewage effluent is that the river becomes seriously polluted during the first rushes of storm water.

21096. Could you give us an analysis of a typical sample of your road water during the early period of a storm?—Yes. A sample of road water taken in principal streets during first rushes of storm gave the following analysis:—

Oxygen absorbed in 3 minutes - -	12·50	
Oxygen absorbed in 4 hours - -	19·90	
Ammoniacal nitrogen - - - -	1·11	
Albuminoid nitrogen - - - -	·49	
Chlorine - - - - - -	8·7	
Suspended solids, vol. - - - -	25	
Suspended solids, non-vol. - - -	59	=84
Solids in solution, vol. - - -	22	
Solids in solution, non-vol. - -	51	=73
Total solids - - - - - -		157

21097. Have you any information as to the bacteriological condition of the road water?—No.

21098. Do you consider that in certain circumstances the road water should be purified?—I consider that road water should have some form of rough treatment, such as settlement in tanks, before being passed into a stream.

21099. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers?—I have not had any experience with the separate systems of sewers.

21100. Is your sewage settled, and, if so, how?—Our sewage is settled after the addition of chemicals.

21101. Do you prefer to use precipitation tanks in series or in parallel?—I prefer to work the tanks in parallel, thus getting a divided quantity of sewage in each tank, and consequently a more gentle flow through the tanks.

21102. In the case of continuous flow tanks, do you think there is any advantage in the employment of baffling boards or walls?—I do not find much to be gained by baffling walls. I have tried both methods—that is, with and without—and did not find any benefit from the walls. They were a source of considerable inconvenience during sludging operations. Scum or fat boards at the outlet end I find very effective in keeping the floating matter from passing on the filters.

21103. How is the sludging of tanks done at your works? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from the tanks?—The sludging at our works is done in two methods. Two tanks have Candy's travelling sludge removers erected in them. These work by a syphonic action, and deliver the sludge into a deep channel running between the two tanks, which is connected to the sludge culvert. After the syphon has been started the machine is made to travel along racked rails (upon which it is mounted) by means of pinion gearing actuated by hand. This method has the advantage of the tanks not being run off for sludging operations. A large quantity of water is brought over by the apparatus, and the tanks are not nearly so well freed from sludge as are the other four tanks, which are sludged by means of running as much liquor off as possible and then sweeping the whole of the sludge out of the tanks. With care it can be arranged that the tank previously sludged can be filling during the period the next tank is being run off for sludging, and thus preventing any extra rush being turned on the filters. We have one day's storage capacity.

21104. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—It is far better to remove the heavy road detritus as a first operation, particularly where the sludge has to be pumped after being removed from the tanks. The grit from the road surfaces has a very serious effect on the brass plungers and valves in the pumps. In cases where no pumping is required I still think it advisable to remove the road detritus as a first operation, as this matter in times of storm is of great bulk and settles in the tanks an inert substance, and rapidly diminishes the capacity of the tanks.

21105. You have had experience of chemical precipitation of sewage?—Yes.

21106. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—My experience at Heywood has been that a chemically treated sewage was more easily treated in the contact filters than a sewage treated in a septic tank.

21107. Have you tried various chemicals? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—I have tried various chemicals. Iron and alumina compounds have been used under such trade names as alumite, kremnolite, ferrozone, aluminoferric, etc. Aluminoferric is the best precipitant tried at Heywood. With an addition of 8 grains per gallon a purification of 62 per cent. is brought about. This equals £1 7s. 6d. per million gallons. Ferrozone under the same conditions brought about a purification of 57 per cent., equal to a cost of £1 6s. 6d. per million gallons. Thus for 3·6 per cent. reduction in price 8 per cent. less purification was obtained by ferrozone.

21108. What is the most effective way of adding chemicals?—In solution of known strength.

21109. What is the average analysis of the liquor from your precipitation tanks? What length of time does the sewage remain in the tanks?—The average analysis is as follows:—

Oxygen absorbed (4 hours' test) - -	3·38
Chlorine - - - - - - -	6·7
Ammoniacal nitrogen - - - -	1·99
Albuminoid nitrogen - - - -	·42
Nitric nitrogen - - - - -	Traces
Suspended solids - - - - -	4·0

An effluent containing as low as 2 parts per 100,000 is often obtained. When storm flows are turned through the tanks the suspended solid figure gets as high as 25 parts per 100,000. The rate of flow in dry weather is 24 hours.

21110. What is the character of the suspended matter in such liquor?—The suspended solids consist of broken cotton fibres, insoluble soaps, small particles of the precipitate, aluminium hydrate, and gelatinous albuminoids, which give a cloudy appearance to the effluent. In times of storms fine particles of clay, straw, etc.

21111. Do you find it necessary to add further chemicals to the sludge before it can be dealt with? If so, for what reasons, and what chemicals do you use, and how are they added?—We find it necessary to add a small quantity of lime to the sludge to keep it porous and to prevent it sticking to the sheets. The quantity added is 1·2 per cent., and it is mixed just previous to the sludge being passed into the ejectors.

21112. What is the manurial value of the sludge obtained by the chemical precipitation of the sewage at your works, and will farmers take it?—The manurial value of the sludge is good. It is all taken by local farmers, and large crops are raised from it. It contains on analysis:—

Moisture - -	56·23
Organic matter -	19·95
Mineral matter -	23·82
	100·00
Nitrogen equal to	·95 of ammonia.
Phosphate of lime	1·44

21113. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—The smell from the tanks is only offensive during sludging operations. There are no dwellings near, and consequently no complaints have been made.

21114. As regard septic tanks, how should they be shaped?—Rectangular, length about four times the width.

21115. Should they be divided into sections?—Not in the tank proper. When not preceded by catch-pits, a grit chamber should be built at the inlet end, which could be cleaned without disturbing the tank.

21116. Should they be used in series or in parallel?—In parallel.

21117. Is a scum necessary or desirable?—I do not think scum is absolutely necessary, but it is desirable. A scum has the advantage of keeping the smell down, and, further, keeps the lighter solids over the whole surface, and thus prevents them being washed out of the tanks before they have been resolved into simpler compounds.

21118. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—I do not think a septic tank need be covered when a fair distance from any dwellings, but should dwellings be near it would be a good plan to cover the tank and thus avoid nuisance from smell.

21119. What do you consider the best arrangement for the "feed" and "draw-off"?—Dibbing inlets and bent outlets, as shown in the sketch below:—



21120. At what rate is sewage, as a matter of custom, passed through your septic tanks?—At the rate of the dry weather flow of 24 hours.

21121. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous? Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with?—I consider the best method of working septic tanks is to have the tank liquor coming away as uniform as possible, and to get this, with either a weak or strong sewage, the tank should have a capacity equal to 24 hours' dry weather flow. In this manner we get the varying strengths mixed as far as practicable, and a fairly even flow going on to the filters. My experience is that when the flow is increased up to the rate of three times the dry weather flow the sludge which has settled in the tank is disturbed, and portions pass over with the tank liquor, which is decidedly disadvantageous.

21122. Is it possible to "over-septicise" a sewage, and, if so, for what reasons, and how is the "over-septicising" brought about?—It is possible by too slow-working of septic tanks to get the effluent giving off very offensive odours of sulphuretted hydrogen.

21123. What is the amount of digestion in your septic tanks, and how do you calculate this?—My experiments were conducted in a small tank not suitable for making calculations as to digestion. A large tank is now at work which will shortly be available for calculations. The amount of digestion I should calculate from the solids in the sewage minus the solids in the effluent plus the sludge.

21124. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?—I find it better not to take small portions of the sludge out of the tanks at short intervals, as this disturbs the tank, and it is necessary to allow time for settling. I find it better to let the tank run a fair length of time and then remove all the sludge.

21125. How often would you clean out the sludge?—Circumstances would have to govern the period of cleaning. I should not let the tank get half full of sludge; when it was approaching this I should empty it.

21126. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—The sludge should be removed by drawing as much water off as possible, and then passing the sludge through a pipe at the bottom of the tank, to be dealt with in the sludge presses, and afterwards burned. A very offensive smel is given off, which would no doubt be a nuisance if dwellings were near.

21127. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank?—Yes.

21128. What amounts of suspended solid, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—In the small tank the solids were not determined, but the increase was very perceptible in the appearance of the samples. In some samples I examined from a neighbouring authority the solids in suspension, after starting, averaged 3 parts per 100,000. A number of samples examined when the tank had been working six months contained 9 parts per

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100,000 of suspended solids. The sewage is of a weak character.

21129. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—I do not find it advisable to pass storm water through septic tanks at a greater rate than twice the average dry weather flow.

21130. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank, and, if so, can you give us figures (in parts per 100,000) showing what the increase is?—Yes. A considerable increase in the amount of suspended solids takes place when storm sewage is passed through the tanks at the rate of three times the dry weather flow. The suspended solids have increased up to 38 parts per 100,000 in times of storm.

21131. Have you made any observations as to the effect of raising the ordinary level of the liquid in a septic tank through the admission of storm sewage or the use of automatic gear?—Our tanks would not permit of the level being raised, and I have therefore not been able to try this method.

21132. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor?—In practice at Heywood I do not find that septic tank liquor is more easily treated than precipitated sewage. We get on an average 64 per cent. purification in the filters treating precipitated sewage, whilst the filters treating septic tank liquor gave only 53 per cent. The suspended solids in the septic tank effluent were more abundant than the solids in the precipitated effluent by appearance. The suspended solids were not regularly determined during the experiments.

21133. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—I have no data.

21134. Have you any data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints?—No.

21135. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—A very offensive smell is given off, and if houses were in the near vicinity I think complaints would be made.

21136. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—I think it is essential that the solids in sewage should be removed as far as practicable. The practicable limit would be lower in a chemically treated sewage than in a septic sewage. Four parts per 100,000 could be attained in a chemically treated sewage, whilst 8 parts per 100,000 should be aimed at for septic tank effluents.

21137. What, in your opinion, is the best way of removing suspended solids?—A well-constructed tank with suitable inlets and outlets ought to answer.

21138. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?—I have no practical experience of either mechanical arrangements or special tanks. The solids in the tank effluent could be reduced very considerably by means of a mechanical filter, or centrifugal action in tanks. The expense in the first method and the head required in the second method would be great disadvantages.

21139. What other (if any) method of dealing with tank liquor before delivering it to filters do you regard as necessary or desirable?—I do not think any further treatment is necessary before being delivered to the filters.

21140. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement. I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis. In framing your answer, please take into account the question of nuisance, the subsequent dealing with the sludge, the subsequent purification of the tank liquors, and the annual cost as well as the initial expenditure. It may be that with some kinds of sewage you would prefer one method and with other kinds another. If so, perhaps you would kindly indicate what rules you think should determine the choice?—My experience is limited on this question. I have only had experience with quiescent settlement with chemicals, continuous flow settlement with chemicals, septic tank treatment. The sewage has been treated as it has arrived at the works, irrespective of the result—that is to say, no extra period of settlement has been given to reduce the suspended matter to one figure. In actual practice this is not possible. As regards quiescent settlement: In this method the same amounts of chemicals were used as in the continuous settlement. A slightly better result on the average was obtained. The disadvantage of the system was that more attention, and consequently extra labour, was required. Secondly, the effluent was not at all even. The tank which received the night flow when run off was exceptionally weak, and the tank which received the day sewage was correspondingly strong when run off; in fact, we got almost the same degree of variation as appeared in the incoming sewage. The equalisation of continuous settlement was lost and extra labour required. As regards continuous flow settlement: This method did not give quite so good results as the quiescent settlement, but the effluent was more uniform and the labour less. The percentage purification was 62, and the cost of filtering was about equal. As regards septic tank treatment: In this form of treatment the tank purification is only 36 per cent., against the above 62 per cent. Considerable saving is affected in chemicals, which will in Heywood amount to £353 per annum. We calculate a further saving of nearly one-half the sludge pressing. In the case of septic treatment double contact beds were required to get an effluent as satisfactory as a chemically precipitated effluent and one contact. So whilst a saving in chemicals is effected by septic tank treatment, the area of beds to be constructed would be increased in the proportion of 100 for chemical precipitation and 166 for septic tank treatment.

The following is the annual cost at Heywood for the three systems, contact beds being used in all cases:—

	Continuous Flow Settlement.	Quiescent Settlement.	Septic Tanks.
	£ s. d.	£ s. d.	£ s. d.
Cost per annum for sludge pressing	662 16 2	662 16 2	340 0 0
Cost per annum for chemicals and labour	821 6 3	854 13 7	—
Cost of labour in attention and sludging	—	—	381 6 0
Interest and sinking funds on capital expenditure	1,317 0 4	1,317 0 4	1,533 5 0
	2,801 2 9	2,834 11 1	2,254 11 0

The double contact bed did not work long enough to make a calculation as to the period of sludging up. The risk of nuisance is greater in septic tank treatment.

21141. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—It is advisable to construct contact beds

of building materials when the site is limited, but where the area of the site is unlimited, and the levels are such as would permit the beds being excavated out of good ground, *e.g.*, clay, then it may be advisable for economy to construct them without walls; but in all cases I think some impervious material should be placed in the bed to prevent the soil being worked up into the filtering material.

21142. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—I think a bed should not be more than four feet in depth, for I find that the rate of purification is not so rapid at and below this depth as in the upper layers of the bed.

21143. What do you consider is the most convenient size for a contact bed?—From one-ninth to one-twelfth the units; so that if a bed is thrown out of use for a rest it should not put so much area out of use.

21144. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—Gas coke gave slightly better results than clinker in our experiments, but it had a greater tendency to fall. In our district well-burned furnace and destructor clinker is the best material, which can be got in bulk.

21145. What size should the filtering material be, and should it be graded in the beds?—The sizes we found to work well were, for first contact beds, to pass 1½-inch mesh and be rejected by ½-inch mesh; second contact beds, to pass ½-inch mesh and be rejected by ¼-inch mesh. I don't think the material should be graded in the beds. It is advisable to place a small quantity of fine material near the inlet troughs; by this means a large quantity of suspended matter is prevented from entering the bed.

21146. How should the bottom of the bed be constructed?—Of impervious material, slightly inclined towards the outlet, and well drained with perforated pipes.

21147. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—Yes.

21148. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary beds and for secondary beds?—The most satisfactory results were obtained on the first contact beds by the following periods: One hour filling; two hours full; half-hour emptying; four and a half hours resting. The second contact beds were worked at the following rate, being of the same size as the first contact beds: Half-hour filling; two hours full; half-hour emptying; five hours resting.

21149. How should contact beds be filled and emptied?—Under personal control.

21150. If you have had experience of automatic gear for filling and emptying contact beds, would you kindly give your views of such gear?—I have not had any practical experience of automatic gear for working filters. On our beds I fixed electric contacts, and by this means a large bell was rung when the bed was nearly full, thus saving constant attention and overfilling of the beds.

21151. What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed in 24 hours? If the amount varies with the quality of the tank liquor, please state by analytical figures what quality of tank liquor you are assuming in your answer, and how differences in the tank liquor affect the amount that can be properly treated?—I found that three fillings per day, equalling 100 gallons per cubic yard, with a septic tank liquor containing ·35 parts of albuminoid nitrogen, and absorbing 5·25 parts of oxygen in the four hours test, gave a percentage purification of 50 on the oxygen figure, and ·36 on the abuminoid nitrogen. I don't see how in actual practice it would be possible to give a variable contact with various strengths of sewage, as the sewage has to be dealt with as it arrives at the works, and the strength is highest when the flow is highest.

21152. What amount of liquid from a primary bed can in practice be properly treated on each cubic yard of filtering material of a secondary bed in 24 hours?—About 1½ times the quantity treated on the first contact bed.

21153. Can these quantities be increased by more frequent filling and emptying in times of storm without impairing the efficiency of the beds or the quality of the effluents?—Yes, with storm water proper, provided the suspended solids have been considerably reduced. The storm water should be passed through the beds at the same time as the weak storm effluent from the septic tanks. The tank liquor which comes out of the tank when storm water is admitted is very strong for the first few hours, and this could not be passed through the bed effectively at a quicker rate.

21154. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent? If so, please state in precise terms (*i.e.*, by analytical figures) of what tank liquors you are speaking, and what effluent you are regarding as satisfactory?—I think one contact is sufficient for weak tank liquors from Sunday sewages or a well-settled storm water where the four hours oxygen absorbed figure is as low as 2·5 parts per 100,000 and the albuminoid nitrogen ·20. These figures could be reduced by one contact down to 1 part for the oxygen absorbed figure and about ·1 for the albuminoid figure, which I should consider a satisfactory effluent.

21155. At what rate or rates do primary contact beds and secondary contact beds lose their water-holding capacity?—At the commencement our primary beds had a capacity of 49 per cent., and the secondary beds 50 per cent. After working 40 weeks and receiving 720 fillings the capacity of the primary bed was 32·2 per cent. and the secondary bed 34·5 per cent. In the single contact beds treating the chemically precipitated effluent the capacity remains fairly constant. Rough measurements have been made from time to time by means of a weir, the capacity being about 32 per cent. Careful actual measurements were made on October 13th, 1902. After working four years and ten months and receiving 3,972 fillings the capacity was then 34·42 per cent. The last actual measurement was made on March 22nd, 1905, after working six years and three months and receiving from the previous actual 2,420 fillings, or a total of 6,392 fillings since bed commenced, the capacity was then 31·9 per cent. The following is an analysis of the liquor which was being treated:—

Oxygen absorbed, four hours' test	3·38
Chlorine	6·7
Ammoniacal nitrogen	1·99
Albuminoid nitrogen	·42
Nitric nitrogen	Traces.
Suspended solids	4·0

21156. What causes the loss of capacity?—With our beds treating the precipitated sewage the loss of capacity is due to the gelatinous growth on the material. This grows fairly regularly when the usual volume of water is treated. The capacity can be restored by resting the bed. With the beds treating septic tank liquor the diminution in capacity was more rapid, and did not regain its capacity to the same extent, proving that the loss of capacity is due to the solid matter which is passed on the bed.

21157. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard?—I have tried to wash the beds by means of a current of water turned in an upward current through the bed, using the effluent from the other beds. This was not satisfactory, as the head available was not sufficient. The best method I know of is to remove the material from the beds and pass it through a revolving screen along with a supply of water. It is said that this method costs 1s. per cubic yard, but I think 2s. would be nearer the mark.

21157*. How can the capacity of contact beds be best maintained?—By giving regular periods of rest and by placing a layer of fine material at the top of the beds, and replacing this as it becomes choked.

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21158. What is the average analysis of your single contact effluent and of your double contact effluent?—The average analyses are as follow:—

	First Contact.	Second Contact.
Oxygen absorbed 4 hours' test	2·69	1·08
Chlorine	7·4	7·2
Ammoniacal nitrogen	·93	·49
Albuminoid nitrogen	·19	·10
Nitric nitrogen	Occasional traces	·61
Putrescibility	All	7·20
Solids	Not determined	

21158*. Can you state the number of gallons of liquid treated daily per cubic yard of filter material in your first bed, and the number of gallons treated daily per cubic yard of filter material in the two beds?—Yes; 170 gallons per cubic yard on the first contact bed or 85 gallons per cubic yard on the combined beds.

21159. Do you find any chemical poisons in your final effluent?—No, judging from the action on fish life.

21160. What is the average amount of suspended matter in the effluents? Does most of this come out with the first flush or not?—During the experiments suspended solids were not regularly determined. The first rushes always contained the greater proportion of suspended solids.

21161. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed is different from the organic matter of the suspended solids going on to that bed?—I do not find the proportion of the organic to inorganic matter to vary much in the solids going on a bed and the solids leaving the bed. I generally find solids going on the bed to contain about 3 per cent. more organic matter than the solids leaving. The solids leaving a bed are granular in appearance, and settle quickly; the solids going on the bed do not settle rapidly, and are more gelatinous in appearance, and keep in suspension and give a cloudy appearance.

21162. Is the first flush of effluent from either set of beds ever putrescible?—Yes.

21163. Do you find that by increasing the number of fillings in storm times or other times the amount of suspended solids is increased?—Only slightly.

21164. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency, and, if so, do you think there are advantages in so working them?—I do not think there is any advantage in using a contact filter as a streaming filter in times of storm. The whole of the bed is not brought into use, and there is a great tendency to choke the beds near the inlet.

21165. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per 24 hours in ordinary times and in storm times. Please state whether you have single or double contact, and what is the depth of your beds?—Our single contact beds are constructed very elaborately, and the cost works out at £21,240 per acre, but only 1,340 square yards are constructed. We treat the tank liquor at the rate of 822,800 gallons per acre. We do not attempt to pass more than 1,097,000 gallons per acre through in times of storm. The beds are 3 ft. deep.

21166. Have you made any experiments which throw light upon the action of contact beds when full and when resting?—The observations I have made in regard to the action of contact beds have been with various lengths of contacts, the rate of purification at various depths of the bed, and also running the tank liquor through the beds immediately after the bed has been discharged and after it has had its usual period of resting empty. The following are averages of some analyses under the above conditions:—

	Tank liquor.	Continuous flow after filter has been run off.	Continuous flow after filter has had period of rest.
Oxygen absorbed (4 hours test)	2·00	1·31	0·87
Ammoniacal nitrogen	2·29	1·95	1·15
Albuminoid nitrogen	·42	·28	·26
Nitric nitrogen	Nil	Traces	·77

21167. Have you made a study of the conditions of aeration of contact beds?—No.

21168. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—I do not find any nuisance whatever from the treatment of sewage on contact beds.

21168*. As regards continuous or percolating filters, what do you find are the best filtering materials, and what size should the material be?—Well-burned destructor and furnace clinker of size from 4in. to 2in.

21169. What depth should a percolating bed be to obtain a good effluent? If this varies with the quality of the liquid going on, or with the size of the filtering material, please state how it varies, what depths you require for different liquids, and how you would distinguish one liquid from another, *i.e.*, what analytical figures you would rely on for this purpose?—I have tried two depths of beds, one of 3ft. and one 8ft. The 3ft. bed was not satisfactory when dealing with a strong tank liquor, though with diluted tank liquors and weak Sunday sewages absorbing two or three parts of oxygen it gave an effluent which would satisfy the requirements of the Mersey and Irwell Joint Committee, but on ordinary days it was not satisfactory. With an 8ft. bed the effluent was always within the requirements of the Mersey and Irwell Joint Committee. For a weak liquor a less depth answers; say under three parts per 100,000 in the four hours' oxygen absorbed test and under ·2 parts per 100,000 of albuminoid nitrogen, a 3ft. would give a satisfactory effluent. In depths between three to eight feet I have not had experience with.

21170. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?—Yes.

21170*. Is the material better disposed in the form of two beds, to be fed in succession with the same liquid, or in one deep bed?—The material is in my opinion better disposed of in one bed, particularly if the levels of the land are such that every inch is available. The collecting of the effluent and consequent redistribution of the liquid on the second bed would loose from 2ft. to 3ft. I tried two 3ft. beds in succession, and the effluent for a time was of a very satisfactory nature. Gradually the humus matter from the first bed formed an almost impervious layer on the surface of the second bed and prevented the free access of the liquid. The top layer was removed, washed, and replaced. In the course of a further three months the top had again become choked, and the experiment was given up. The conditions did not allow of a settling tank being fixed between the two beds.

21171. How should percolating filters be fed?—By means of sprinkling or spreading the liquid over the whole area of the bed.

21172. Should the feed be intermittent or continuous?—Intermittent.

21173. What is the best form of distribution? What, in your opinion, are the conditions which have to be fulfilled by a perfect distributor, having regard not merely to the distribution of the liquid itself, but also to the purification of the liquid and the life of the bed?—Revolving spreaders. They should deliver the liquid evenly over the whole suface of the bed, and should not be interfered with by either wind or frost. The sprinkler should work with a minimum of friction if the beds are to be kept in a healthy condition.

21174. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—A filter could easily deal with a large volume of tank liquor in times of storm. I should not pass the liquor on at abnormal rates (say three times the dry weather flow), but should prefer to pass the liquor on at the usual rate, and arrange an apparatus which would bring more beds into operation, and whilst the storm lasted the beds would have a less interval of rest. If the storm water was dealt with, as previously mentioned, by a special tank, it could be so manipulated that whilst the filter had a larger volume of liquid to deal with, the total impurities would not be increased in the same degree.

21175. Is there any practical advantage in artificially heating the liquid which is being treated on percolating filters?—Assuming that the effluent from a bed artificially heated is slightly better than the effluent from a bed at ordinary sewage temperature, the increase in cost would outweigh any advantage gained, and would therefore not be a practical advantage.

21176. Have you had any experience to show whether open sides are an advantage to a percolating filter?—I have not made any experiments as to the value of open over closed sides, though, as the changes required are aerobic, it seems that open sides would be most suitable. Our new beds at Heywood are to be constructed with open sides.

21177. Have you made any study of the conditions of aeration of percolating filters?—No.

21178. What do you consider is the most convenient superficial area for a percolating filter?—This would be guided to a great extent by the amount of sewage delivered at the works. Care should be taken that the beds are not over large in comparison to the flow, so that if one bed has to be put out of action through accident or being sick the other beds should not be overburdened.

21179. Do you think it desirable that the bottom of a percolating filter should be raised from the ground?—Yes. It is very important that a percolating bed should be on a false floor, so that the humus matter can drop free from the filtering material, and thus be easily removed, otherwise the bottom layer of clinkers would become choked. The raised or false floor also gives better aeration to the lower portions of the bed.

21180. Do percolating beds, in your experience, choke?—I did not find that the single bed choked to any appreciable extent. After two months' working there appeared to be a fairly regular discharge of humus matter in ordinary times of working. When excessive volumes of water were turned on the bed it brought away large amounts of black matter. If choking did occur it suggests that by rushing a large quantity of water on the bed the material could be freed from these deposits which accumulate on the filtering material. As the material would not have to be removed for this operation, the cost of retreatment of the liquid would be the heaviest item of expenditure, and this would not be excessive.

21181. Of what nature are the suspended solids in the filter effluent? How much is organic matter, and are they putrescible apart from the liquid portion of the effluent?—The solids coming away from the percolating filter were granular in appearance, and settled fairly rapidly. They contained on the average

52·5 per cent inorganic matter
47·5 per cent organic matter.

The solid matter, apart from the liquid, upon incubation undergoes secondary decomposition in from three to five days at 80° F.

21182. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a percolating filter is different from the organic matter of the suspended solids going to that filter?—The organic solids issuing from the percolating bed are more granular in appearance than the solids on the bed. The solids settle more rapidly, and are not as glutinous in character as the solids going on the bed.

21183. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter, and to what minimum figure do you think such settlement or other final treatment can be carried as a practical measure?—I conducted experiments with a view of ascertaining the amount of settlement required to get an effluent practically free from suspended matter. The greater portion had settled in two hours. In three hours there were only traces, whilst at the end of four hours the effluent was practically free from suspended matter. It is quite practical to obtain an effluent with suspended solids not exceeding 3 parts per 100,000.

21184. Do you find that the suspended solids in your filter effluent vary much in amount from time to time, and, if so, can you explain the causes of such variation?—During ordinary flows the suspended solids in the filter effluent appeared to be fairly even. When large flows were turned on the beds the suspended matter was increased, the large flow washing the sediment out of the bed.

21185. What was the cost of your percolating bed installation per acre, and how much liquid do you treat?—Our percolating bed was only an experimental one, and not suitable for calculating cost. The estimate for the twelve beds, 60 ft. diameter, 8 ft. deep, about to be put down, is £9,500 per acre. We propose treating 643,720 gallons per acre in dry weather and 1,936,000 per acre in 24 hours in wet weather as a maximum, though we never get this rate continuous for 24 hours.

21186. Have you made any experiments which throw light on the action of percolating filters with regard to the oxidation of the ammoniacal and organic matter in solution and the organic matter in suspension?—No.

21187. Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter, or that they are first absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one?—No.

21188. Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter?—I do not find the atmospheric temperature variations to have any great effect on the working of the beds. In frosty weather the temperature of the sewage averages 11° Centigrade.

21189. Have you found any trouble from vegetable growths in percolating filters? If so, have you been able to form any opinion as to the causes of these growths and as to the way in which the growths can be prevented?—When the supply to the beds was continuous a gelatinous mass grew on the surface of the bed. This was overcome by working the beds intermittently.

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21190. Do you find any nuisance from the treatment of sewage on percolating filters? Have any complaints been made?—The odour from a percolating bed is much more in evidence than the odour from a contact bed, and the risk of nuisance is greater. No complaints have been made, as dwellings are not near.

21191. Would you kindly compare the cost (initial expenditure and annual cost of upkeep and working) and relative advantages of percolating filters and contact beds? Do you consider that one form is best for some kinds of the sewage and the other form for other kinds of sewage?—I am of opinion that the percolating filter could be constructed at a less cost than double the area of contact beds with the necessary inlet and outlet channels, valves, etc. Some of the advantages a percolating filter has over a contact bed are that the upper layers of the filter do not become choked as soon as contact beds ; they are more easily cleaned, and, being more compact, they require less supervision ; more perfect distribution can be obtained ; and they can be worked more automatically. I find the percolating filter most suitable for our sewage, and for sewages generally.

21192. Do you find that the chance of nuisance is any greater with one form of filter than with another? Does the risk of nuisance depend on the kind of sewage which is being treated or on the nature of the preliminary treatment to which the sewage has been subjected? The question of nuisance is important, and I should be glad if you would state your views fully on these points?—The risk of nuisance does not depend on the kind of sewage or the preliminary treatment so much as the fact that in a percolating filter the liquor is delivered in the form of a number of small jets or sprays, therefore having a greater tendency to liberate any offensive gases or odours which the liquid may contain. If two similar liquids were passed on a contact bed in the ordinary manner, and on a percolating filter, there would be more odour given off from the percolating bed.

21193. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor or tank liquors could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds? If so, would you kindly state the results, at the same time telling us in precise terms what was the composition of your tank liquor or tank liquors, and what you are considering to be a satisfactory effluent?—In actual practice we treated on our contact beds 170 gallons per cubic yard on each bed, or 85 gallons per cubic yard on the combined beds. On the percolating bed 100 gallons per cubic yard were treated. The result was a much better effluent from the percolating bed than from the contact bed. The following is the average analyses on the two systems :—

	Contact System.		Percolating System.		
	Tank.	2nd Contact.	Tank.	Bed Effluent.	Settled Effluent (two hours).
Oxygen absorbed (4 hours' test)	5·25	1·08	5·54	1·22	0·83
Ammoniacal nitrogen	1·36	·49	3·40	·51	·51
Albuminoid nitrogen	·38	·10	·78	·12	·10
Nitric nitrogen	nil	·66	nil	1·46	1·40
Chlorine	7·7	7·6	8·3	8·1	8·1
Solids in suspension	—	—	9	5	1·5

I consider the settled effluent to be of a fairly good type.

21194. Could you express an opinion as to how the number of gallons would vary with variations in the strength of your tank liquor, and on what figure or figures you would rely for defining the "strength" of your tank liquor?—No. I don't think it practical to decrease the volume according to strength. In our works we get the largest dry weather flow when the sewage is strongest, *i.e.*, between 10 a.m. and 5 p.m. The beds have to be worked in the same ratio as the flow, with a corresponding decrease in the quality of the effluent.

21195. Have you had experience of storm water filters? If so, would you kindly give us the results of it?—We have storm filters in operation at both our works. I find the action of the storm filters is more mechanical than chemical. The sewage passes through at such a rate that there is no time for bacterial action. The action is merely a retention of part of the suspended solids on the material.

21196. Do you consider storm water filters lose any of their efficiency by being used intermittently at long intervals?—In the method of working, storm filters do not acquire the efficiency of either contact beds or percolating filters. The efficiency of our beds, which is one straining, is not affected by long intervals of rest.

21197. Have you any practical suggestions to make for disposing of sludges?—The screening refuse is very offensive and should be burned in a destructor ; the material from detritus tanks soon loses its offensiveness, and may be tipped on low-lying lands ; the sludge from precipitation tanks should be pressed, and either burned or used as manure ; and the sludge from septic tanks should be pressed and burned along with ashpit refuse.

21198. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?—There is very little nuisance caused by burning sludge. In using sludge as manure there is danger of farmers storing it near public roads and footpaths, and causing a nuisance in this manner. Very strong complaints were made to us during last summer, and orders were issued forbidding farmers to stack the sludge near public roads.

21199. What, in your opinion, constitutes a good effluent?—In my opinion a good effluent is one (a) which will not absorb more than ·7 parts of oxygen from $KMnO_4$ in four hours ; (b) which does not contain more than ·07 parts of albuminoid nitrogen ; (c) which will not undergo secondary decomposition when incubated at 80° F. for five days ; (d) which will not destroy more than its own volume of aerated tap water when incubated at 80° F. for 48 hours ; (e) which contains an abundance of nitric nitrogen.

21200. Do you consider that the type of effluent form a contact bed is superior or inferior to the type of effluent from a percolating filter?—I consider an effluent from a percolating filter to be of a better type than an effluent from a contact bed. In a percolating bed effluent the general impurities I find less, the effluent better aerated and better nitrated. The suspended solids settle more readily, and the effluent is less liable to undergo secondary decomposition.

21201. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—The tests I chiefly rely on are the oxygen absorbed figures from $KMnO_4$, 3 minutes and 4 hours, and the albuminoid nitrogen. These tests are the tests acknowledged by the Mersey and Irwell Joint Committee, under whose jurisdiction our works are. Apart from this I consider the tests to give the best idea as to the purity of an effluent. The oxygen test is one which any intelligent manager could make, and thus be enabled to know the condition of the works. The secondary decomposition and aeration tests I consider very valuable.

21202. Have you tried the "aeration" test, *i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—Yes ; though not systematically, until Mr.

Scudder brought out his modification of the indigo method.

21203. Is one standard for all effluents passing into non-potable streams possible and desirable, or should there be more than one standard?—I think a general standard ought to be aimed at, which, whilst not overburdening the authorities, would safeguard our rivers. Different standards for different authorities I am afraid would not be favourably received by those authorities who unfortunately had to conform to the higher standard. The following modified Mersey and Irwell Joint Committee standard I consider liberal, and could be obtained by a good proportion with ease:—Oxygen absorbed from $KMnO_4$ in 4 hours, 1·50; albuminoid nitrogen, ·12; to be non-putrescible when incubated for 5 days at 80° F.; not to destroy more than two volumes of aerated tap water when incubated at 80° F. for 48 hours; should have nitric nitrogen present, and organic solids in suspension should not exceed 1·5; all in parts per 100,000.

21204. What is your experience of the effect of storm water upon filters of various sorts?—My experience is that storm water has a very serious effect on the upper layers of contact beds. When large quantities of storm water are turned on contact beds, the upper layers rapidly become choked. The same action takes place on storm filters; the solid matter accumulates on the surface of the beds, and has to be removed periodically. If the storm water was settled in a tank previously to going on the filters, a great deal of this trouble would be obviated.

21205. How far do you consider it advisable for a sewage installation to be worked automatically?—In percolating installations working intermittently I consider an automatic apparatus an essential feature. The apparatus should act over a great variation of flow, say from 1 to 12, so as to enable it to deal satisfactorily with the minimum night flow and the maximum day flow. It should be so arranged that it will deliver the low night flow on to one bed for any desired length of time, and at the end of this period it should automatically divert the flow to the next bed. Should the flow increase through rain or any other cause, the apparatus should bring additional beds into operation in ratio to the flow until there are sufficient at work to deal with the maximum flow, in this manner preventing excessive flows being turned on the beds. As the flow decreases the beds should be automatically put out of action in the same ratio as the flow, the cycle of changing being constant, so that all the beds get equal shares of liquid. The apparatus should have a simple arrangement to allow any bed being put out of action for a prolonged rest should necessity arise, though should excessive flow occur and the full resources of the works be required, this bed should automatically come into action during the time of pressure. These are the conditions which a satisfactory distribution should fulfil. I have designed a distributor, which is at work at Heywood, which conforms to all the conditions. With any distributor which will fulfil all these conditions, I think the feeding of the beds may be done automatically with advantage.

21206. Have you made any systematic observations as to the effects of discharging effluents into watercourses? No.

21207. Could you make a short statement setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents, and giving your reasons?—I attach most value to the oxygen absorbed test from $KMnO_4$. Although it does not always bear a strict ratio to the other impurities, yet I always find with a low oxygen absorbed figure that the other impurities are not great. The secondary decomposition I do not find taking place with a low oxygen figure, and the rate at which dissolved oxygen is taken up is low. The chlorine test is always valuable to ascertain whether the sample of effluent is representative of the preceding sample of sewage. The value I attach to the nitrites and nitrates is in ascertaining the condition of the bed. The albuminoid nitrogen I consider gives a good clue to the putrescible matter in the effluent. The rate at which dissolved oxygen is taken up is, I consider, of great importance, as it gives us a good clue as to the effect the effluent will have on the river. The secondary decomposition test is an important one, as it gives a good idea as to whether the effluent is liable to cause a nuisance through developing offensive odours.

21208. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—The following is my idea as to the strength of sewage and tank liquors (parts per 100,000):—

Oxygen absorbed (4 hours' test).	Albuminoid Nitrogen.	——
9 and above	·9 and above	Strong sewage
5 to 9	·5 to ·9	Fairly strong
5 and under	·4 and under	Weak
5 and above	·4 and above	Strong tank liquor
3 to 5	·2 to ·4	Fairly strong
Under 3	Under ·2	Weak tank liquor

21209. On Question 21095, would you tell me on what river you derive your experience which leads you to say that "on a river of thirty times the volume of the inflowing sewage effluent the river becomes seriously polluted during the first rushes of storm water"?—At Heywood, on the River Roach, which flows past our works.

21210. On Question 21122, have you had actual experience that it is possible by too slow working of septic tanks to get the effluent giving off very offensive odours of sulphuretted hydrogen?—Yes. We have in our present works as an experiment a septic tank in slow working and in that tank we invariably get a very offensive odour of sulphuretted hydrogen given off.

21211. You have evidence yourself that that is owing to the fact that the working of it is too slow?—Yes; I could not account for it by any other cause.

21212. In Question 21135, you say that a very offensive smell is given off from the septic tank?—Yes.

21213. Does that come from the tank itself or from the liquid as it passes out of the tank on to the filter?—More particularly from the liquid.

21214. Is it constant or is it only when the tank is working too slow?—One has really to take other people's views on that, because you get so accustomed to being continually on the works that you do not notice any slight odour arising, but people coming down to the works very often complain of the offensive odour.

21215. Many witnesses say that there is no nuisance at all; I do not know whether yours is exceptional?—That is not my experience. My experience is that the odour is offensive.

21216. (*Mr. Power.*) Are your beds fed with a sprinkler?—No, by open troughs.

21217. (*Chairman.*) As regards the question of expense, have you any figures to support your conclusions as stated in Question 21138?—No. The first expression is purely an opinion. We conducted a small experiment by means of a centrifugal tank with baffle plates fixed at the sides, so that as the sewage went over, the solid matter was thrown out by centrifugal action and deposited between the plates. The head that we lost was so great that we could not adopt the system at our works.

21218. On Question 21141, have you had any experience of the soil working up into the filtering material?—Yes. The first filter that we put down was on a clay

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bed, and the clay worked up and made an impervious mass around the drain pipe, so that we had to discard that and put in a concrete bottom. That experiment was carried out with a view to constructing our storm filters with clay bottoms, but we came to the conclusion after that small experiment that it would be a failure. Consequently we concreted the whole area of 6,200 square yards of the storm beds.

21219. In Question 21165 you say that the cost of your single contact beds works out at £21,240 per acre?—Yes.

21220. That is an enormous sum, is it not?—Yes, that is an enormous sum, but our filters are constructed very elaborately, with massive copings, blue bricks, very powerful walls, glazed brick outlet channels, and polished stone approach steps. They are very expensive indeed.

21221. Do you believe them to be worth the money?—They are worth the money, but the money is not necessarily spent. The value is there, but it is to no purpose.

21222. (*Mr. Power.*) I wish to ask one or two questions especially about the storm waters. In Question 21066 you say that your average dry weather flow is between 600,000 and 700,000 gallons per 24 hours?—Yes.

21223. In Question 21070 you tell us that there are no storm overflows fixed on your sewers; that the whole of the storm water is conveyed to the entrance to the sewage works where there is a primary screen, and that the grosser solids are arrested before the storm water passes over the storm overflows to the river. This takes place when you get down six times the dry weather flow, namely, 4,200,000 gallons?—Yes.

21224. Then in Question 21073, speaking of heavy rains, you say "gaugings during very heavy rain have registered at the rate of 30,000,000 gallons per 24 hours." Therefore during part of the day you may have storm water sewage coming down at the rate of 30 times the dry weather flow?—That is so.

21225. That goes directly into the river?—That goes directly into the river after the grosser solids have been removed by the screens.

21226. What is the ratio of your effluent to the river in ordinary times?—One in 30.

21227. And does this storm sewage come down to you before the river is in flood?—Oh, certainly.

21228. Is it a grossly polluting liquid?—Yes, it is grossly polluting, and the first rushes of storm water have a detrimental effect on the river.

21229. Have you considered any method by which that could be dealt with or controlled—or any part of it? I notice that later on you say that twice the dry weather flow is sufficient to deal with by the whole of your process, and you think that the balance—which would be four times or more the fine weather flow—should be dealt with by settlement tanks and then passed on to the percolating filter or straining filter—which was it?—The percolating filter.

21230. That is a deep filter?—Yes.

21231. At what rate?—We propose about 500 gallons a square yard per day of 24 hours. That would work out somewhere about 200 per cubic yard.

21232. Do you think it would be feasible in a case like yours where there are no overflows on the sewer to subject some of the liquid beyond the six times the dry weather flow to settlement, so as to prevent the pollution of the river?—Yes, I think it is quite feasible and that it is far more satisfactory than turning it on to the storm filters as we do at present. In fact, we might increase the flow through the tank and arrest the grosser solids.

21233. As a matter of fact, it is not negligible, because in the course of the year you estimate that 139,000,000 gallons passed to the river in that way?—Yes.

21234. Do you think it would be costly in the sense of greatly increasing the amount of settlement tanks?—It would be very costly in increasing the settlement tanks in proportion to the increased number of volumes we tried to treat.

21235. Are the 30,000,000 per 24 hours in any given day? I suppose that is not maintained? It is a matter of minutes rather than of hours, is it not?—No; we have had that occurring for a full three hours.

21236. What is the greatest amount that has come down to you in one day and been passed through your works to the river? How much in any one day—not 30,000,000 gallons, or anything like it, I suppose?—No.

21237. There would be that 4,200,000 which you have dealt with?—Yes.

21238. In addition, in any given day, how much do you think has passed away to the river?—That is a question I could not answer without calculating the rainfall in our drainage area on any particular day. That would give us what had come down the main sewer in that day.

21239. Do you think it would be at least as much as the 4,000,000 you deal with?—Decidedly more; I should say double the quantity on some very wet days.

21240. How much should you think of this liquid coming at the rate of 30,000,000 gallons in 24 hours is a highly polluting liquid and should be dealt with?—That varies according to circumstances. In Heywood the first one and a half hours—that is the big rush—is undoubtedly very, very foul.

21241. Would it be so much as 12,000,000 gallons, do you think?—No. With 1 in. rainfall it would be 8,409,000 gallons.

21242. You would deal with twice the dry weather flow by the whole plant?—Yes.

21243. And the balance above that has to pass through settlement tanks?—Yes.

21244. And then through percolating filters?—Yes, through percolating filters.

21245. Anyhow, you could pass the balance through a settlement tank and later through a rough filter, I suppose?—Yes, we could do that comfortably. We would get rid of the first one and a half hour's flow—the heavy flow—and then we could give it an hour's settlement, which would give a fairly satisfactory effluent.

21246. What brought about the abolition of overflows on the sewers themselves, or was absence of overflows in the scheme from the first?—It was the opposition of the Mersey and Irwell Joint Committee against having so many different outlets for their inspectors to inspect. It was ultimately decided that we should convey the whole of the storm water to one storm overflow. Of course, another point which is not much in favour of the prevention of pollution of rivers was that the sewers would get a swilling out. That is the pith of the subject.

21247. Then if I might go a little further, I see that you have had some experiments in septic tank filtration?—Yes.

21248. Does your preference for dealing by the whole plant with only two volumes of the dry weather flow extend to the septic tank process?—Yes, more particularly.

21249. If you had a septic tank process instead of your precipitation process, you would prefer to deal with it on exactly the same lines as you propose to deal with the chemical process?—Yes.

21250. (*Major-General Carey.*) About this failure to deal with three times the dry weather flow mentioned in Question 21090. Does the fault not lie in the want of sufficient precipitation?—No.

21251. What is the capacity of your precipitation tank?—710,000 gallons. The chief reason why our effluent is so polluted in times of storm is that the incoming sewage enters almost at the bottom of the tank. The current immediately meets the sludge and throws it up at the other end—that is, the previously settled sludge. Our sewage is not passed in at the top of a tank and gradually run over the surface; it is passed in at the bottom of the tank. This method is perfectly satisfactory in normal times, but immediately a storm comes with an increased flow the velocity is so great at the bottom that the sludge is disturbed and thrown over the outlet.

21252. (*Mr. Power.*) In other words, your tank is filled with suspended matter by the storm water coming into it?—Yes, after the first hour.

21253. Would it be double as much suspended matter?—Sometimes quite double. In fact, we have decided to dispense with that method now—that is, with the method of feeding at the bottom of the tank.

21254. (*Major-General Carey.*) And deliver it at the top?—No, 3ft. from the top.

21255. That will remedy the disturbance of the sludge to some extent?—Yes, to a certain extent it will.

21256. Now about your storm beds. What is the total area of your storm beds?—The total area at the main works is 6,200 square yards, and at the Heap Bridge works, a small works in one of the out districts, 480 square yards.

21257. Is the storm water delivered over the whole or that surface?—It is not; it is delivered by a main trough down the centre.

21258. Does the whole of the area come into play?—No, it does not.

21259. Would not that account in a great measure for a part of it coming up if you simply use part of it?—Yes, we only use a part of it on the immediate side of the trough. Assuming we have here the storm bed with a trough running along down the centre, the flow goes over the trough and flows down at a very rapid rate in the path of the least resistance, which, when the bed is new, is immediately on either side of the trough. That gradually becomes clogged, and the water flows over the top.

21260. That is defective distribution?—Yes, that is purely a storm bed.

21261. If your distribution was better, and you used the whole of the area of the storm filters at your disposal, you would not have any trouble?—We should not have the same trouble, but still we should practically get the same trouble later through having the sludge distributed evenly over the bed in a thin, gradually increasing layer rather than in a large quantity near the trough.

21262. Do you distribute over the whole of that 6,000 yards?—I think so. We have on our storm beds two sprinklers of 60ft. diameter, which are my own patent. I put them down for an experiment there. We get into the sprinkler the storm water, and the whole surface of the bed has become choked in both sprinklers; in three months' time, delivering a maximum of 400 gallons per square yard per wet day, we find the bed is totally clogged.

21263. That only occurs at intervals?—No; the rate that I give you is calculated on six months' working.

21264. (*Mr. Power.*) What is the size of the material?—It is a 1in. mesh at the bottom; the material has been rejected by a 1in. mesh, but the upper 18in. has passed the 1in. mesh and been rejected by the $\frac{3}{4}$in. mesh.

21265. As a matter of practice, do you deal with the bed by forking the surface over continually?—No. I would rather wait until it dried and skim it cleanly off. It dries rapidly on the top, and the men can skim it off entirely.

21266. But the suspended matter involves the filter for some depth from the surface, does it not?—No, not more than two or three inches.

21267. (*Major-General Carey.*) On Question 21126: Would the nuisance caused by drawing off the sludge be removed or abated by emptying the tanks more frequently? You say, "A very offensive smell is given off, which would no doubt be a nuisance if dwellings were near." That is in emptying your septic tanks?—Yes, and the chemical precipitation tanks.

21268. Would that nuisance be removed or abated if you emptied the tanks more frequently?—No.

21269. I am speaking of the septic tank?—Yes, but we get the same odour from both tanks, but more particularly from the septic tank. A strong odour, however, is produced by the chemical precipitation tank.

21270. On Question 21152 will you kindly explain how one and a half times the volume put on the first contact bed can be treated on the second contact bed?—Assuming that the area of the first contact bed be 100, then the second contact bed would go down approximately to about 66.

21271. But you say about one and a half times the quantity of the first contact bed?—Yes, one and a half times the volume. That is, supposing we get 200 gallons through the first contact bed, then we can get on our area 300 per yard satisfactorily treated on the second contact beds. You diminish the second contact beds proportionately in area as $1\frac{1}{2}$ is to 1.

21272. But you cannot get more on the second contact bed than goes through the first?—Yes, we can get more through by diminishing the area.

21273. By diminishing the area, otherwise the charge must be the same?—Provided one delivered directly on to the other; but if it delivers into a channel from which the diminished area is filled, then we could get an increased volume per cubic yard through the second contact bed.

21274. In reply to Question 21158*, you say that 170 gallons per cubic yard can be treated on the first contact bed, or 85 gallons per cubic yard on the combined beds?—Yes. That just comes back to the previous question. During the time of the experiments we had two beds exactly the same size, the first contact bed and the second bed; we were compelled always to turn direct from the first contact bed on to the second contact, as we had not a channel between where we could turn it and increase the flow on a given bed. This is an actual experience with equal volumes on each bed. After that I tried some short experiments with feeding the second contact beds at more rapid intervals, and I found out that we could get one and a half times the volume through.

21275. (*Mr. Power.*) By giving it less contact?—By giving it less contact and a slightly less period of rest.

21276. (*Major-General Carey.*) The volume treated on the combined beds at both first and second contact is one and a half times the volume treated on the first contact?—No. You treat your 170 gallons per cubic yard; then in the combined beds you get double the area, and consequently you reduce the volume. Double area, half volume.

21277. (*Mr. Stafford.*) In your answer to Question 21140 you compare the cost of the three methods—quiescent settlement method, continuous flow settlement, and septic tank treatment—and apparently the septic tank treatment is the cheapest?—Yes.

21278. And the least efficient of the three?—No, they are of about equal efficiency. These are worked out on equal efficiency.

21279. But I see that the percentage of purification was 62 in one case, while in the case of the tank effluent it was only 36?—That is so.

21280. Thirty-six?—That is so; and then I have calculated the extra interest on the set of contact beds to bring them up to one standard, as we had to do. My actual experience is that chemical precipitation and one contact is about equal to septic tank and double contact; that has been my experience at Heywood.

21280*. Where do you bring it in?—In the interest and sinking fund on capital expenditure.

21281. £1,533 5s.?—Yes. I have accounted for that in the question because we should require a larger area of beds, and therefore I have worked out the cost of the increased interest and sinking fund in the same ratio.

21282. (*Colonel Harding.*) Returning for a moment to one of the points raised by Mr. Power and General Carey, viz., the storm waters: I suppose you have no doubt as to your figures of having at times brought to your works 40 times the dry weather flow?—Not the slightest.

21283. One is surprised to find that your sewer mains should be capable of bringing to the works such an enormous quantity?—Oh, they could deliver double that quantity.

21284. Does it not involve that the flow during normal times is exceptionally slow?—Fairly slow, but with an egg-shaped culvert.

21285. That corrects the flow to a certain extent. Is it a flat or a hilly country?—It is fairly hilly. Our main outfall sewer is a brick culvert 3ft. 6in. by 2ft. 6in., which will easily deliver that volume.

21286. You have told us what we have been told by others before, that in storm times the amount of suspended matter in the sewage is greatly increased?—Very greatly.

21287. And you have given us the result of an interesting experiment taken every hour during a storm, from which it appears that during the first rush you had up to 238 parts per 100,000 of suspended matter, and after several hours it had fallen to 18?—Yes.

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21288. One gathers, therefore, that the impurities of storm waters consist mainly of suspended matter?—Decidedly so.

21289. In Question 21089 you tell us, nevertheless, that the liquid part of the sewage during storm times during the first two hours is very foul, do you not?—Yes. It is a foul liquid, but I am speaking there purely in comparison with the effluent. I am speaking of it as it goes to the river, not as sewage.

21290. I see. It is foul relatively to the excellence of the effluent which you ordinarily turn into the river, but not necessarily foul as compared with the ordinary dry weather sewage?—No; you have the correct interpretation there.

21291. Am I right in understanding that what you mean is that the impurities in storm water are mainly in the form of suspended matter, and that when the suspended matter has been removed you really relatively have a dilute liquid which is not foul?—That is so.

21292. The example which you give just before in Question 21089 shows that after you have removed the suspended matter the liquid which is not so good, no doubt, as your ordinary effluent is greatly better than your ordinary sewage?—Decidedly so.

21293. Does it not appear that the main business in connection with storm water is the removal of suspended matter?—That, in my opinion, would be the most satisfactory method of dealing with storm water—to give it an hour's settlement and get out the suspended matter.

21294. You do not advise that being done through the ordinary tanks, either the chemical precipitation or the septic tanks? You think there should be a special series of tanks?—A special tank, yes.

21295. So as not to disturb the normal condition?—That is so.

21296. The plan of storm filters which you have actually worked consisted in turning this unprecipitated storm water upon the storm bed?—Yes.

21297. And you find that the action of the storm bed is unsatisfactory because the action is rather mechanical than chemical?—That is so.

21298. It is, in fact, a strainer?—Pure and simple.

21299. And not a very efficient strainer, probably?—No.

21300. And it is difficult, after the straining, to remove the matters strained off?—The sludge that accumulates on the surface, yes.

21301. You would prefer settlement in tanks?—Yes.

21302. Having settled storm water, further treatment would not be difficult, if required, would it, upon percolating beds?—I do not think so.

21303. You have percolating beds, have you not?—We have only two sprinklers, but part of the storm filters works as a percolating bed.

21304. But you have not experimented in putting settled storm water on the percolating beds?—No.

21305. You have expressed the opinion that probably double the flow might be treated as settled water?—Yes. In fact, at present we are getting out quantities for constructing 12 60-ft. diameter percolating beds, and that is our object—to increase the flow in times of storm.

21306. Do you believe it would be easier to deal with a large flow of settled storm water on percolating beds than it would be upon contact beds?—I do.

21307. In Question 21106 you express the opinion that it would be easier to filter chemically precipitated sewage than septic tank effluent. Is that not because the chemically precipitated sewage is much freer from suspended matter?—Yes.

21308. Are you able to give us an opinion, based upon your own experience, as to whether you think it would be easier to deal with chemically precipitated effluent than septic tank effluent, provided suspended matter in both cases was the same?—I could not vouch an opinion upon that, because it is a most difficult matter to reduce the suspended matter in the septic tank effluent down to the same figure as the suspended matter in the chemically precipitated effluent. It would mean some mechanical filtration—some further settlement or mechanical sieving would be necessary to reduce the suspended matter.

21309. What you mean is that, not having had experience of effluent cleared of suspended matter, you are unable to answer the question?—That is so.

21310. (*Mr. Power.*) I suppose, in regard to the facts you speak of here, the precipitation tanks were never used to deal with more than twice the volume of the dry-weather flow?—They are very satisfactory so long as you do not deal with more than twice the dry-weather flow?—That is so. Directly you get above that you begin to disturb the sludge at the bottom, or get such a rapid flow that you have not time for an efficient settlement.

21311. Then the result would come nearer that with the septic tank?—In that case, so far as regards suspended solids, yes.

31312. (*Colonel Harding.*) You have told us of the difficulty which you find in reducing the suspended matter in septic effluent to the low point which you desire?—Yes.

21313. It would be very important if the septic effluent could be obtained with much less suspended matter?—Yes.

21314. You have not any idea of how it could be obtained, have you? Have you tried any experiments?—We tried a circular tank with baffle plates, but the head we lost was so great.

21315. You told us that. But that did not succeed. Have you heard of any other way by which it might possibly be done?—Yes, I have heard of mechanical filtration by means of passing it through felt. The experiment was carried on in the neighbourhood close to us, at Ratcliffe. It was a mechanical filter whereby the liquid was passed on to a long felt band and filtered through the felt. The felt was gradually moving, and brushes were brought into action later on to clean off the sediment which had been collected on the band. The band was then passed under revolving rollers and presented again to the sewage.

21316. Probably it was found that a very thin volume of sediment would cause the felt to be quite impervious?—That is so, but the felt was always moving and always being cleaned.

21317. But was it successful at all?—The expense was too great. It was discarded.

21318. It was prohibitive?—Yes, and it was discarded entirely.

21319. You have not found that passing the septic effluent through a second settling tank gets rid of any part of the suspended matter?—I have not had an opportunity of testing that.

21320. (*Mr. Power.*) Is your septic plant on a small scale?—Yes, but there is one at work now with a capacity of 110,000 gallons.

21321. How long has that been in operation?—That has been in operation since February 22.

21322. So that you have had no great experience of it yet?—Yes. I have some analyses, but they are not in the state I should like them to be in yet. I have not sufficient figures to vouch any special opinion, but I could tell roughly the percentage of purification on the oxygen test. We are improving very considerably on what we did on the small one. Our percentage of purification on the large tank, based on the oxygen-absorbed test, is 55.

21323. The greatest flow during rain would be what?—Not more than double the dry-weather flow. We limited it to that. Do you mean the average dry weather flow?

21324. Not the average; the quickest rate would be one in 12 hours?—Yes.

21325. (*Colonel Harding.*) What is the amount of suspended matter in the sewage when going into the tank in that experiment?—It is the same as in the chemical precipitation, which runs at about 38 or 39.

21326. What is the amount of suspended matter coming out in the septic tank effluent?—We do not get very satisfactory results there; we get often eight or nine parts, particularly now. It appears to be going worse now. The sludge is rising from the bottom and is thrown over the outlet sill until we get seven, eight, or nine parts.

21327. (*Mr. Power.*) You have not had much sludge since February, have you, in a septic tank of that size?—A fairly large amount; it is beginning to rise considerably now.

21328. (*Mr. Power.*) That is rather rapid production of sludge, is it not?——

21329. (*Colonel Harding.*) Yes; one would scarcely expect it to be very full at present?—(*Witness.*) When I speak of the rising of the sludge I do not refer to rising in depth; I mean the gases are now beginning——

21330. (*Colonel Harding.*) You mean the septic action is developing?—The septic action has disturbed it, yes.

21331. I thought the sludge was accumulating?—No, that would be rapid.

21332. Do you find the amount of suspended matter in the effluent is also increasing?—That also is increasing.

21333. Naturally, as the tank accumulates sludge that will continue to increase?—That is so.

21334. Until it reaches a prohibitive point, and then you will clear out the tank?—Yes.

21335. That leads me to ask you whether it would not be very valuable if you could maintain a constant capacity in the septic tank by not waiting until the tank is practically full of sludge, but by emptying some sludge daily or weekly so as to maintain a constant capacity?—That would be perfectly satisfactory, in my opinion, if the works were designed with that object in view.

21336. Is it practicable, do you think, to construct tanks to attain that object?—Yes, simply by constructing an extra tank so that you could give a tank a rest.

21337. If it is possible, do you think it desirable?—Yes.

21338. So as to maintain a constant capacity?—Yes.

21339 To prevent the increase of suspended matter in the effluent from the septic tank?—Yes. My evidence was based purely on the conditions under which I have to work.

21340. You have said something about the scum on the septic tank being in your opinion of no practical value unless it be in keeping in the smell?—Yes.

21341. How can the scum do that?—Will you refer me to the question.

21342. It is in answer to Question 21117. You say, "A scum has the advantage of keeping the smell down." Would you mind telling us how?—That was very noticeable in our small tank when we had a scum on. In calm weather the smell was not so noticeable as it was when the wind had disturbed the scum and cleared it off the tank.

21343. But the fact of there being a scum there does not prevent the evolution of gases?—No.

21344. The scum is not impervious; it does not confine the gases?—No. But in windy weather when there is no scum, there is a gradual current of the upper layer of water. As the wind drives this water along the surface of the tank, it is replaced by water from a lower depth, and thus we get more water exposed, and consequently a more offensive odour given off.

21345. You express a similar opinion with regard to covered septic tanks; that a covering might be useful in cases where it was important to keep down the smell. There again, how does the cover of the septic tank prevent the escape of gases. They cannot be for ever confined and accumulated under the cover of the septic tank, can they?—No, but if there was any offensive odour given off you must have the gases confined and conveyed to some method of destruction.

21346. The utility of the cover would be to enable you to carry away the gases—possibly to burn them?—Yes, that is so.

21347. Or to make them innocuous in some way?—Yes, that was my point. In that case you would have control of the offensive gases.

21348. Do not the gases consist mainly of methane, and hydrogen, and so on?—But in the long working of a tank we get a decidedly offensive odour.

21349. Is not that due to the movement of the septic tank effluent?—No, as the tanks work too slowly we get a black effluent and an offensive odour.

21350. By over septicising there is a production of hydrogen or other evil-smelling gases?—Yes.

21351. In reply to Question 21126 you make an interesting suggestion about the burning of the pressed sludge from septic tanks. Have you any experience of that process at all?—Yes, we have tried it at our small tanks. We took the sludge up to the destructor, which is in close proximity to the works, where it was burnt along with the ashpit refuse. We got no offensive odour at all from it.

21352. Would it be expensive to burn the cake from the septic tanks sludge?—I do not think the expense would be great apart from the carting of the sludge to the destructor.

21353. There would be a considerable amount of moisture in it?—Yes.

21354. You are of opinion from the small experiment you made that the burning of septic tank cake would be practicable, and that it would not be offensive?—I think that would be the best means of disposing of sludge—by burning.

21355. In reply to Question 21142 you expressed the opinion that a contact bed ought not to be deeper than 4ft. Upon what do you base that opinion?—By inserting tubes in the filter and withdrawing portions of the effluent and testing it, we find that the purification oxidation is more rapid in the upper layers.

21356. That is a point of considerable interest. You have tried a bed much deeper than 4ft., and at different points you put in tubes which enabled you to test the part below 4ft., but below 4ft. you got no practical improvement?—We do not get the same purification in any way to the same degree lower down. In fact, in some experiments that I worked out we got at 6ft. in two hours an equal purification to that which we got in a quarter of an hour in the first foot of the bed—that is, at a depth of 6ft. in two hours you get the same oxidation as you get in a quarter of an hour in the first foot of the bed.

21357. Let us quite understand what you mean. What was the depth of the experimental bed?—6ft.

21358. And at each foot had you a tube which you could withdraw?—Tubes with corks at the top.

21359. How did you extract the liquid?—It rises in the tube.

21360. And you found that the percentage of oxidation in the first foot was greater than in the last?—Yes.

21361. One can appreciate that, but did you not find an improvement in purification as you went to greater depths? In other words, would the results of purication on a bed 4ft. deep be better or worse than the purification on a bed 6ft. deep?—I think that would depend entirely on the method of feeding. When you do down in a rapid stream as we do down the side of the bed by a trough you do not get the same proportion. I found, according to some figures which I give later, that the first rushes coming down the bed washed out the nitrates; we get a well-nitrated effluent, but by continually running through we do not get the same amount of purification.

21362. Your uneven distribution to a certain extent vitiated the experiment?—That is so.

21363. Do you think that with reasonably good distribution upon a contact bed 6ft. deep the greater part of the bed would be acting during filling as a percolating bed?—That is so.

21364. And likewise during the process of emptying it would be acting as a percolating bed, and its greater depth would give it a great advantage in regard to those periods of the process?—My opinion is that with proper distribution you would get an advantage by deeper bed.

21365. We are not to take it that your opinion is that there is no advantage in carrying a contact bed to a greater depth than 4ft.?—There is no advantage. But I form that opinion on the method of distribution that we have. We get the effluent run down in a trough.

21366. Then we are to modify the opinion that you expressed to that extent—that in your special circumstances it is no use having a greater depth than 4ft., but you think that in other conditions there probably would be an advantage in deepening the bed?—But it would then be more on the lines of a percolating bed.

21367. Then, passing on to the percolating bed, you have told us that if it is put on the percolating bed

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it necessarily involves that suspended matter will come out in the filtrate from the bed, and that if the flow be at times considerably increased the discharge of suspended matter will also be considerably increased, and, that at those times it comes out, I think you say, in the form of humus?—Yes.

21368. I suppose in normal times the suspended matter in the filtrate is brown—earthy?—Yes.

21369. But if the discharge is at a much greater rate of flow than usual it would be scarcely humus, but probably black and unoxydised?—That is so, and far larger quantities. By holding the sprinklers in one position we can bring about the same action.

21370. You have reached the conclusion that such accumulations as take place in a sufficiently coarse percolating bed may be washed out by an increased flow?—Yes.

21371. In any case, unless you have thoroughly clarified sewage on the percolating bed you must have suspended matter in the flow?—That is so.

21372. What process do you suggest as the best to follow percolating filtration in those conditions?—I think the large settling tank in all cases ought to follow the percolating bed.

21373. Have you tried the process of settlement following percolation?—Yes.

21374. What results have you obtained? How low were you able to bring down the suspended matter in filtrates afterwards settled?—We could easily get down to one, and generally in four hours it is practically free from suspended matter. There is no appreciable suspended matter after four hours' settlement.

21375. You think that with percolating filters which receive suspended matter there must be a further process?—Decidedly so.

21376. And the further process which you suggest as efficient is settling?—Yes, a settling tank.

21377. There occurs to me a rather interesting point. If you are obliged to have subsequent settlement following percolation, it does not very much matter how much suspended matter you bring to the filter, does it? You might have imperfectly settled sewage, if it was going through the filter and was afterwards to be settled?—My opinion is that the suspended matter in unoxydised effluent is more gelatinous in form, and does not settle nearly so rapidly as the humus matter which comes away from the percolating bed.

21378. I quite appreciate that. That is an advantage of subsequent settlement; but suppose you put crude sewage upon a percolating filter which was sufficiently coarse, you would get a large quantity of suspended matter coming out in the filtrate?—Yes.

21379. Would the suspended matter which you had then be better settled following filtration than preceding filtration? I think you said that the matter coming out after filtration is to a large extent oxidised, that it is granular, and that it settles rapidly. Would you think it likely that settlement following upon filtration might be substituted for settlement preceding filtration?—I do not think so; I think the product would be the same. We should still have the glutinous form of sludge if the bed was overworked.

21380. If the bed was overworked?—Yes.

21381. But one is assuming that it is not overworked?—That would be tolerably slow.

21382. However, you have not had experience in that, and you are not prepared to express an opinion, as I gather?—That is so.

21383. But you have noticed that the suspended matter coming out of the percolating beds is more granular and more easily settled than the suspended matter in sewage?—That is so.

21384. In reply to Question 21189 you refer to vegetable fungoid growths on the surface of percolating filters. I am interested to see that you think that intermittence in the feed tends to prevent that?—Yes; that was very noticeable.

21385. In reply to Question 21190 you expressed the opinion that percolating filtration is more likely to give rise to a nuisance than contact?—Yes.

21386. Why so, assuming that in both cases the same effluent is put on?—Because if the liquid is offensive, if it contains offensive gases, there is far more chance of the gases being liberated when the flow is divided up into a small number of sprays than there is in rushing it over a weir.

21387. We understand that. Possibly the nuisance would arise not from the filtration, but from the spray which precedes?—Yes, that is so.

21388. From your answer to Question 21193 I gather that you think you could pass a larger volume per cubic yard through percolating beds than through contact beds, and also obtain better results?—Yes.

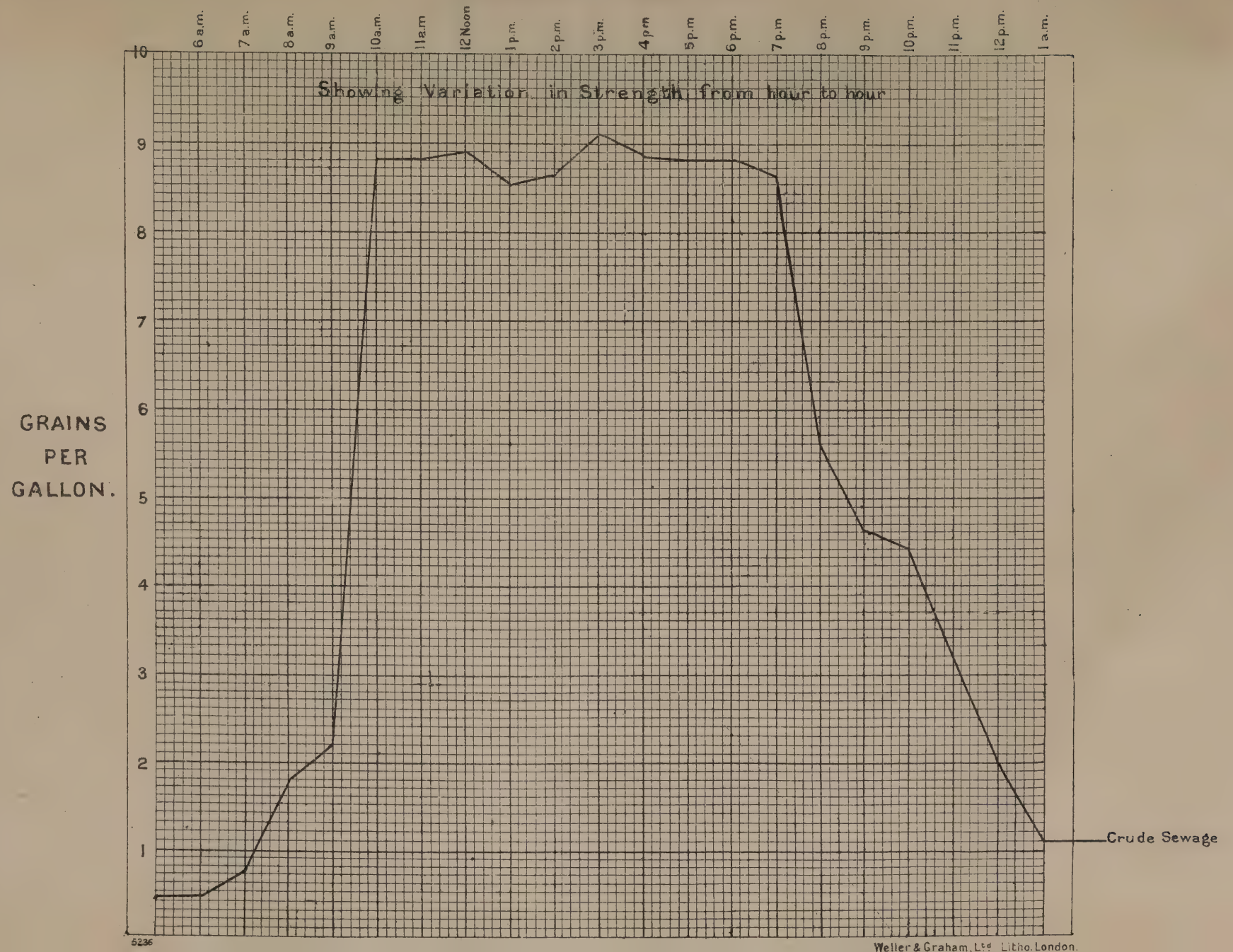
21389. You are assuming, of course, that the liquid treated will be the same? You do not mean that the results of your percolation have been better than the results of contact under different conditions, but with the same effluent from the septic tank or from chemical precipitation you think you can get more volume through a percolating filter per cubic yard than through a contact bed, and also get better results?—And also get better results, yes. That is shown in the analyses which I give.

HANDED IN BY Mr JOSHUA BOLTON.

HEYWOOD CORPORATION SEWAGE WORKS.

No. 1.

DIAGRAM OF ANALYSIS.



5236

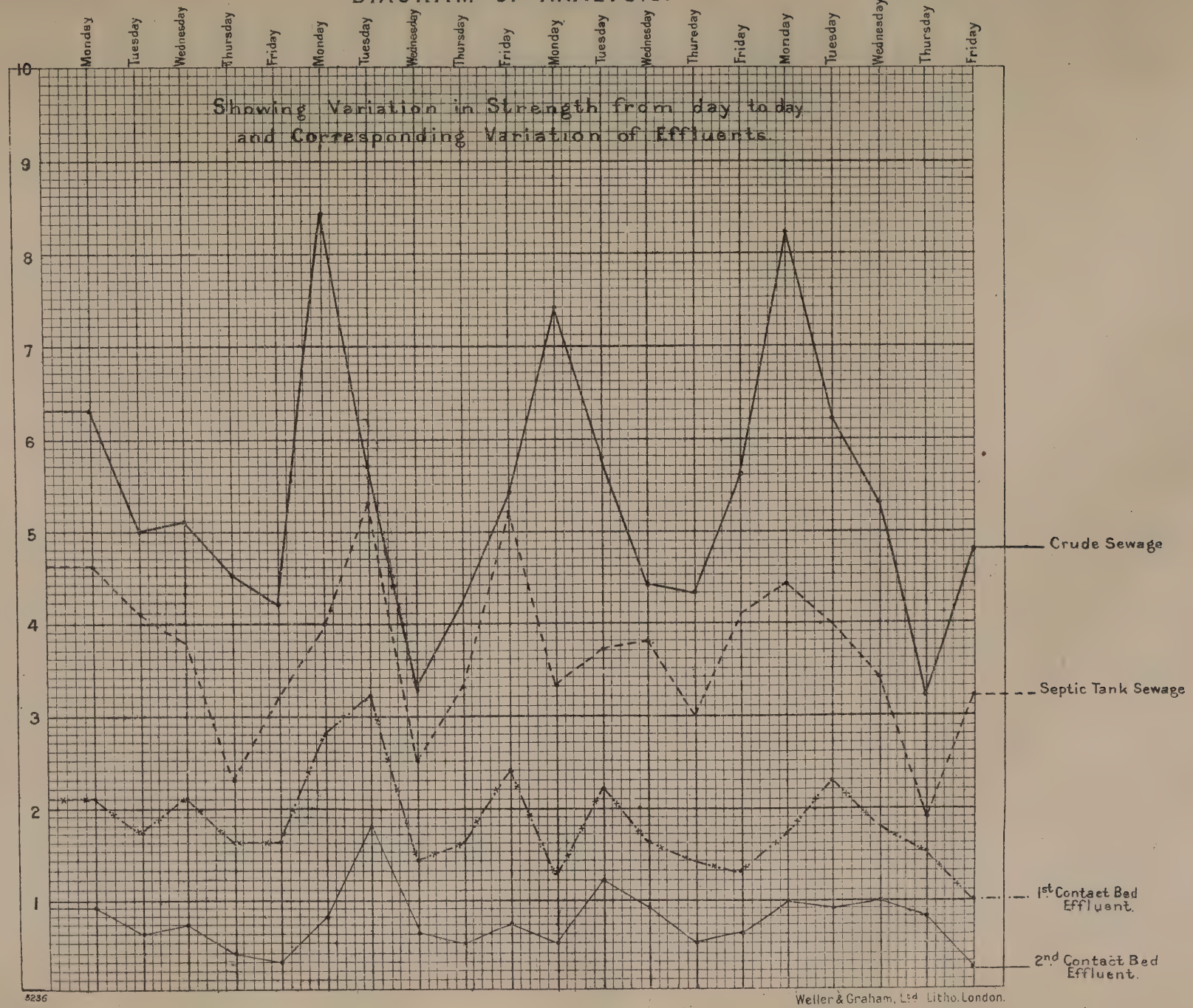
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HANDED IN BY M. JOSHUA DOLTON.

HEYWOOD CORPORATION SEWAGE WORKS.

No. 2.

DIAGRAM OF ANALYSIS.



5236

Weller & Graham, Ltd Litho. London.

HEYWOOD.

Appendix to Evidence of Mr. Joshua Bolton.

Tables showing average analyses of sewage, tank liquor, and filter effluents at Bolton, January, 1903—August, 1904.

PROCESS OF TREATMENT:

Chemical Precipitation and Single Contact Beds.

HEYWOOD. January, 1903.

SEWAGE—

Average daily flow	1,412,548 gallons	Month's rainfall	3·65 inches.
Maximum daily flow	2,930,625 „	Rainfall	·56 „
Minimum daily flow	645,373 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·63	3·78	3·17
Albuminoid Nitrogen	·68	·92	·80
Nitric Nitrogen	nil	nil	nil
Chlorine	5·90	6·8	5·9 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	6·20	8·26	7·17 „ „
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks	1,412,548 gallons = to 11 hours 3 minutes in tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used during month	9 tons 19 cwts.
Amount of Sludge dealt with during month	1,495 tons 15 cwts.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·68	2·76	2 14
Albuminoid Nitrogen	·28	·35	·29
Nitric Nitrogen	trace	nil	—
Chlorine	5·8	6·8	5·2 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	1·78	3·60	2·45 „ „
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS.

Number of times Beds were filled during month	99.
Average duration of contact	1 hour 50 minutes.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours)	185.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·26	3·62	2·91
Albuminoid Nitrogen	·10	·31	·21
Nitric Nitrogen	·42	·09	·23
Chlorine	5·6	6·5	5·5 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	·79	1·53	1·13 „ „
Dissolved Oxygen	·40	·14	·25
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

REMARKS.—The samples of Filter Effluent have generally a slightly turbid appearance, but are free from smell and contain no suspended matter.

February 1st, 1903. *Joshua Bolton.*

HEYWOOD—*continued.*

February, 1903.

SEWAGE—

Average daily flow - - - 1,286,821 gallons - Month's rainfall - - - - 3·42 inches.

Maximum daily flow - - - 2,616,000 „ - Rainfall - - - - - - ·12 „ (Snow previous day)

Minimum daily flow - - - 694,500 „ - Rainfall - - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·08	3·60	2·58
Albuminoid Nitrogen	·52	·92	·72
Nitric Nitrogen	nil	nil	nil
Chlorine	6·8	7·32	6·9 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	4·82	8·72	7·15 „ 20
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=4.

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - - - 1,286,821 gallons=to 12 hours 8 minutes in tanks.

Average number of Tanks in use - - - - - - - - - $5\frac{1}{2}$.

Amount of Chemicals used during month - - - - - - - 9 tons 10 cwts.

Amount of Sludge dealt with during month - - - - - - 1,390 tons 12 cwts.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·71	3·10	2·29
Albuminoid Nitrogen	·38	·58	·45
Nitric Nitrogen	trace	nil	nil
Chlorine	6·8	7·2	6·7 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	1·90	3·40	2·40 „ 20
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=4.

FILTERS—

Number of times Beds were filled during month - - - - - 84.

Average duration of contact - - - - - - - - - - 2 hours.

Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 174.

Average Analysis of Filter Affluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·14	2·86	2·37
Albuminoid Nitrogen	·14	·30	·19
Nitric Nitrogen	·71	·17	·44
Chlorine	6·8	7·6	6·6 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	·86	1·21	1·07 „ 20
Dissolved Oxygen	·46	·27	·36
Suspended solids	—	—	—

Number of samples analysed for the average=4.

REMARKS.—The samples this month have been generally clearer than last month, and have been quite free from smell.

Joshua Bolton.

March 1st, 1903.

HEYWOOD—*continued.*

March, 1903.

SEWAGE—

Average daily flow - - - 1,573,000 gallons - Month's rainfall - - - - 3·73 inches
Maximum daily flow - - - 3,407,250 „ - Rainfall - - - - - ·47 „
Minimun daily flow - - - 680,000 „ - Rainfall - - - - - ·01 „

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·93	4·11	3·81
Albuminoid Nitrogen	·63	1·47	1·07
Nitric Nitrogen	nil	nil	nil
Chlorine	5·0	6·5	6·5 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	3·0	9·71	5·88 „ 20
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - - 1,573,000 gallons = to 10 hours in Tanks.
Average number of Tanks in use - - - - - - - - 5½.
Amount of Chemicals used during month - - - - - - - 9 tons 10 cwts.
Amount of Sludge dealt with during month - - - - - - 1,495 tons 15 cwts.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·69	1·81	1·94
Albuminoid Nitrogen	·24	·38	·29
Nitric Nitrogen	trace	nil	—
Chlorine	6·2	6·7	6·4 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	1·78	2·86	1·98 „ 20
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS—

Number of times Beds were filled during month - - - - - 96.
Average duration of contact - - - - - - - - - 1 hour 55 minutes.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 178.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·52	1·40	1·32
Albuminoid Nitrogen	·10	·14	·10
Nitric Nitrogen	·68	·31	·69
Chlorine	4·2	6·4	6·4 av. of 20
Oxygen absorbed from $KMnO_4$ in 4 hours	·40	1·30	·66 „ 20
Dissolved Oxygen	·65	·71	·49
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

REMARKS.—The Filter Effluent has been on the whole fairly clear, and containing no suspended matter, and being free from smell.

Joshua Bolton.

April 1st, 1903.

HEYWOOD—*continued.*

April, 1903.

SEWAGE—

Average daily flow - - - 882,366 gallons - Month's rainfall - - - - 2·19 inches
Maximum daily flow - - 1,541,625 „ - Rainfall - - - - - ·15 „
Minimum daily flow (Sunday) - 511,875 „ - Rainfall - - - - - ·01 „

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	3·67	3·27	3·30 av. of 3
Albuminoid Nitrogen	·88	·74	·81 „ 3
Nitric Nitrogen	nil	nil	nil
Chlorine	7·8	9·0	8·3 av. of 18
Oxygen absorbed from $KMnO_4$ in 4 hours	8·42	9·71	6·25 „ 18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

TANK LIQUOR—

Average daily flow through Tanks - - - - - - - - - 882,366 gallons = to 17 hours. 42 minutes in Tanks.
Average number of Tanks in use - - - - - - - - - $5\frac{1}{2}$.
Amount of Chemicals used during month - - - - - - - 10 tons 19 cwts. 3 qrs.
Amount of Sludge dealt with during month - - - - - - 1,405 tons 4 cwts.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·69	2·34	2·55 av. of 3
Albuminoid Nitrogen	·27	·53	·39 „ 3
Nitric Nitrogen	trace	nil	—
Chlorine	6·2	7·1	7·5 av. of 18
Oxygen absorbed from $KMnO_4$ in 4 hours	1·78	2·50	2·25 „ 18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

FILTERS—

Number of times Beds were filled during month - - - - - 90.
Average duration of contact - - - - - - - 2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 2 hours) - 168 gallons.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·20	1·81	1·76 av. of 4
Albuminoid Nitrogen	·10	·22	·14 „ 4
Nitric Nitrogen	·56	trace	·30 „ 4
Chlorine	7·8	7·0	7·4 „ 18
Oxygen absorbed from $KMnO_4$ in 4 hours	·44	1·32	·74 „ 18
Dissolved Oxygen	·42	·04	·21 „ 4
Suspended solids	—	—	—

REMARKS.—The Filter samples are almost clear, and contain only a very small quantity of suspended matter.

Joshua Bolton.

May 1st, 1903.

HEYWOOD—*continued.*

June, 1903.

SEWAGE—

Average daily flow	709,133 gallons	Month's rainfall	1·62 inches.
Maximum daily flow	1,513,500 „	Rainfall	·66 „
Minimum daily flow	451,500 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·21	3·78	3·30 av. of 3
Albuminoid Nitrogen	·56	·89	·69 „ 3
Nitric Nitrogen	nil	nil	nil.
Chlorine	6·6	7·9	7·6 av. of 18
Oxygen absorbed from $KMnO_4$ in 4 hours	6·21	8·28	8·27 „ 18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

TANK LIQUOR—

Average daily flow through the Tanks	709,133 gallons = to 22 hours 5 minutes in tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used during month	10 tons 15 cwts.
Amount of Sludge dealt with during month	1,340 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·78	2·42	2·29 av. of 3
Albuminoid Nitrogen	·28	·55	·42 „ 3
Nitric Nitrogen	nil	nil	nil.
Chlorine	6·8	7·0	7·5 av. of 18
Oxygen absorbed from $KMnO_4$ in 4 hours	2·02	2·56	2 83 „ 18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

FILTERS—

Number of times Beds were filled during month	90.
Average duration of contact	2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours)	167.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·98	1·92	1·55 av. of 3
Albuminoid Nitrogen	·11	·23	·17 „ 3
Nitric Nitrogen	·41	trace.	·32 „ 3
Chlorine	6·6	7·0	7·3 „ 18
Oxygen absorbed from $KMnO_4$ in 4 hours	0·61	1·23	·96 „ 18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

REMARKS.—The Filter samples are fairly clear, with only slight traces of suspended matter.

July 1st, 1903. *Joshua Bolton.*

HEYWOOD—*continued.*

July, 1903.

SEWAGE–

Average daily flow - - - 760,358 gallons - Month's rainfall - - - - - 3·92 inches
Maximum daily flow - - - 1,615,875 „ - Rainfall - - - - - - ·65 „
Minimum daily flow (Sunday) 487,500 „ - Rainfall - - - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·68	4·25	3.38 av. of 3
Albuminoid Nitrogen	·41	·69	·54 „ 3
Nitric Nitrogen	nil.	nil.	nil.
Chlorine	7·4	8·6	7·8 av. of 15
Oxygen absorbed from $KMnO_4$ in 4 hours	6·36	9·01	7·84 „ 15
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - - 760,358 gallons = to 21 hours 19 minutes in tanks.
Average number of Tanks in use - - - - - - - - - $5\frac{1}{2}$.
Amount of Chemicals used during month - - - - - - 11 tons 11 cwts.
Amount of Sludge dealt with during month - - - - - - 1,603 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·22	4·50	3·25 av. of 3
Albuminoid Nitrogen	·38	·60	·46 „ 3
Nitric Nitrogen	nil.	nil.	nil.
Chlorine	7·4	8·0	7·2 av. of 15
Oxygen absorbed from $KMnO_4$ in 4 hours	2·35	5·17	3·10 „ 15
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

FILTERS—

Number of times Beds were filled during month - - - - - 93.
Average duration of contact - - - - - - - - - - - 2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 167.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·98	4·50	3·05 av. of 3
Albuminoid Nitrogen	·14	·25	·19 „ 3
Nitric Nitrogen	·42	·23	·32 „ 3
Chlorine	7·2	8·3	7·1 „ 15
Oxygen absorbed from $KMnO_4$ in 4 hours	·52	1·57	·99 „ 15
Dissolved Oxygen taken up in 24 hours	–	—	—
Suspended solids	—	—	—

REMARKS.—Filter Effluent fairly clear with faint traces of suspended matter.

Aug. 1st. *Joshua Bolton.*

HEYWOOD—*continued.*

August, 1903.

SEWAGE—

Average daily flow	1,244,064 gallons.	Total rainfall	5·48 inches.
Maximum daily flow	3,247,875 „	Rainfall	·66 „
Minimum daily flow	534,750 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

TANK LIQUOR—

Average daily flow through the Tanks	1,244,064 gallons, equal to 12 hours 33 minutes in Tanks.
Average number of Tanks in use	$5\frac{1}{2}$.
Amount of Chemicals used during month	9 tons 13 cwts.
Amount of Sludge dealt with during month	1,188 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

FILTERS—

Number of times Beds were filled during month	72, one week's rest.
Average duration of contact	2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours)	174.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	..
Chlorine	—	—	..
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	..
Dissolved Oxygen taken up in 24 hours	—	—	..
Suspended solids	—	—	..

REMARKS.—No complete analyses of the Sewage or Effluents were made during August owing to Holidays The beds were given one week's rest.

Joshua Bolton.

March 22nd, 1904.

HEYWOOD—*continued.*

September, 1903.

SEWAGE—

Average daily flow - - - 1,031,400 gallons. - Total rainfall - - - - 4·99 inches.

Maximum daily flow - - 2,263,125 „ - Rainfall - - - - - 1·28 „

Minimum daily flow - - - 511,125 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·20	3·82	3·17
Albuminoid Nitrogen	·41	·91	·66
Nitric Nitrogen	nil	nil	nil
Chlorine	8·1	8·7	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	8·08	5·63	6·85
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - - - 1,031,400 gallons = to 15 hours 8 minutes in tanks.

Average number of Tanks in use - - - - - - - - - $5\frac{1}{2}$.

Amount of Chemicals used during month - - - - - - - 10 tons 11 cwts.

Amount of Sludge dealt with during month - - - - - - 1,283 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·65	3·21	2·02
Albuminoid Nitrogen	·17	·64	·45
Nitric Nitrogen	traces	nil	—
Chlorine	7·8	8·00	7·7
Oxygen absorbed from $KMnO_4$ in 4 hours	3·20	3·67	3·24
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS—

Number of times Beds were filled during month - - - - - 90.

Average duration of contact - - - - - - - - - - 2 hours.

Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 178.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·51	1·88	1·63
Albuminoid Nitrogen	0·08	0·15	0·11
Nitric Nitrogen	0·90	traces	0·41
Chlorine	·4	8·2	7 5
Oxygen absorbed from $KMnO_4$ in 4 hours	0·43	1·09	0·78
Dissolved Oxygen	·33	·14	·30
Oxygen absorbed from $KMnO_4$ in 3 minutes	0·10	·28	0·18
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

Joshua Bolton.

March 22, 1904.

HEYWOOD—*continued.*

October, 1903.

SEWAGE—

Average daily flow - - - 1,729,323 gallons. - Total rainfall - - - - 8·81 inches
Maximum daily flow - - - 3,582,750 „ - Rainfall - - - - - ·90 „
Minimum daily flow - - - 918,375 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·24	2·18	1·95
Albuminoid Nitrogen	·24	·60	·41
Nitric Nitrogen	—	—	—
Chlorine	4·28	6·2	5·0
Oxygen absorbed from $KMnO_4$ in 4 hours	2·25	5·00	3·29
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - - 1,729,323 gallons = to 9 hours 1 minute, in tanks.
Average number of Tanks in use - - - - - - - - 5½.
Amount of Chemicals used during month - - - - - - - 7 tons 10 cwts.
Amount of Sludge dealt with during month - - - - - - 1,450 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·65	1·62	1·28
Albuminoid Nitrogen	·14	·31	·22
Nitric Nitrogen	nil	nil	nil
Chlorine	4·4	6·1	5·0
Oxygen absorbed from $KMnO_4$ in 4 hours	2·00	3·47	2·37
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS—

Number of times Beds were filled during month - - - - 93.
Average duration of contact - - - - - - - - - - 2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - - 178.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·17	1·32	·88
Albuminoid Nitrogen	·05	·17	·09
Nitric Nitrogen	·31	·81	·54
Chlorine	4·2	6·0	5·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·93	1·10	·94
Dissolved Oxygen	·56	·33	·41
Oxygen absorbed from $KMnO_4$ in 3 minutes	·10	·16	·11
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

REMARKS.—Owing to the very wet weather during this month the Sewage was of a very weak character.

March 22nd, 1904.

Joshua Bolton.

HEYWOOD—*continued*

November, 1903.

SEWAGE—

Average daily flow - - - 1,404,966 gallons. - Total rainfall - - - - 3·88 inches.

Maximum daily flow - - 3,016,500 „ - Rainfall - - - - - ·73 „

Minimum daily flow - - 841,125 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·60	4·02	3·34
Albuminoid Nitrogen	·55	1·02	·72
Nitric Nitrogen	—	—	—
Chlorine	6·7	7·1	7·1
Oxygen absorbed from $KMnO_4$ in 4 hours	7·62	10·72	8·57
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - 1,404,966 gallons = 11 hours 7 minutes in tanks.

Average number of Tanks in use - - - - - - - $5\frac{1}{2}$.

Amount of Chemicals used during month - - - - 15 tons 8 cwts.

Amount of Sludge dealt with during month - - - - 1,482 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·82	3·18	2·40
Albuminoid Nitrogen	·21	·59	·52
Nitric Nitrogen	traces	nil	—
Chlorine	6·6	7·8	7·1
Oxygen absorbed from $KMnO_4$ in 4 hours	3·80	5·6	4·48
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS—

Number of times Beds were filled during month - - - - - 90.

Average duration of contact - - - - - - - - - 2 hours.

Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 170.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·34	2·61	1·98
Albuminoid Nitrogen	·10	·32	·28
Nitric Nitrogen	·72	nil	·38
Chlorine	6·4	6·0	6·6
Oxygen absorbed from $KMnO_4$ in 4 hours	1·34	2·0	1·95
Dissolved Oxygen	·46	·07	·22
Oxygen absorbed from $KMnO_4$ in 3 minutes	·11	·28	·34
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

REMARKS.—During this month the precipitant, Ferrozone, was used, but the results were not satisfactory.

Joshua Bolton.

March 22nd, 1904.

HEYWOOD—*continued.*

December, 1903.

SEWAGE—

Average daily flow	1,041,548 gallons.	Total rainfall	2·01 inches.
Maximum daily flow	2,323,500 „	Rainfall	·65 „
Minimum daily flow	548,250 „	Rainfall	nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=

TANK LIQUOR—

Average daily flow through the Tanks	1,041,548.
Average number of Tanks in use	5½.
Amount of Chemicals used during month	11 tons 6 cwts.
Amount of Sludge dealt with during month	1,565 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=

FILTERS—

Number of times Beds were filled during month	93.
Average duration of contact	2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours)	172.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine		—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=

REMARKS.—No analyses were made during December.

Joshua Bolton.

March 22nd, 1904.

HEYWOOD—*continued.*

January, 1904.

SEWAGE—

Average daily flow - - - 1,068,290 gallons. - Total rainfall - - - - 3·33 inches
Maximum daily flow - - 2,278,875 „ - Rainfall - - - - - ·74 „
Minimum daily flow - - 509,625 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	3·08	4·30	3·44
Albuminoid Nitrogen	·61	1·08	·90
Nitric Nitrogen	—	—	—
Chlorine	7·0	7·5	7·5
Oxygen absorbed from $KMnO_4$ in 4 hours	6·10	8·87	8·26
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks - - - - - - - 1,068,290 gallons = to 14 hours 37 minutes in tanks.
Average number of Tanks in use - - - - - - - - 5½
Amount of Chemicals used during month - - - - - - 10 tons 11 cwts.
Amount of Sludge dealt with during month - - - - - - 1,468 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·85	1·78	2·27
Albuminoid Nitrogen	·38	·50	·49
Nitric Nitrogen	traces	nil	—
Chlorine	7·5	7·2	7·2
Oxygen absorbed from $KMnO_4$ in 4 hours	3·02	4·43	3·42
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS—

Number of times Beds were filled during month - - - - - 82.
Average duration of contact - - - - - - - - - - 2 hours.
Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 176.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·18	1·31	1·73
Albuminoid Nitrogen	·14	·49	·30
Nitric Nitrogen	·88	·21	·71
Chlorine	7·5	7·1	7·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·74	1·51	·99
Dissolved Oxygen	·43	·28	33
Oxygen absorbed from $KMnO_4$ in 3 minutes	·11	·29	·17
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

REMARKS. -All the beds received 3 days' rest during this month.

Joshua Bolton.

March 22nd, 1904.

HEYWOOD—*continued.*

February, 1904.

SEWAGE—

Average daily flow - - - 1,380,172 gallons. - Total rainfall - - - 3·76 inches.

Maximum daily flow - - 2,831,250 „ - Rainfall - - - - ·60 „

Minimum daily flow - - 718,500 „ - Rainfall - - - - nil.

Average Analysis of Sewage.

	Best.	Worst	Average.
Ammoniacal Nitrogen	3·06	4·40	3·58
Albuminoid Nitrogen	·48	1 20	·71
Nitric Nitrogen	—	—	—
Chlorine	6·8	7·3	6·9
Oxygen absorbed from $KMnO_4$ in 4 hours	6·31	10·08	7·46
Dissolved Oxygen taken up in 24 hours	–	-	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

TANK LIQUOR—

Average daily flow through the Tanks - 1,380,172 gallons.

Average number of Tanks in use - 5½.

Amount of Chemicals used during month - 10 tons 4 cwts.

Amount of Sludge dealt with during month - 1,525 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·85	1·85	1·84
Albuminoid Nitrogen	·30	·37	·35
Nitric Nitrogen	nil	nil	nil
Chlorine	6·8	6·5	6·8
Oxygen absorbed from $KMnO_4$ in 4 hours	2·87	3·57	3·18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS—

Number of times Beds were filled during month. - - - - - 87.

Average duration of contact - - - - - - - - - 2 hours.

Amount of Tank Liquor treated (gallons per cube yard per 24 hours) - 176.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·62	1·35	1·40
Albuminoid Nitrogen	·14	·27	·20
Nitric Nitrogen	·68	·51	·71
Chlorine	6 6	7·1	6·6
Oxygen absorbed from $KMnO_4$ in 4 hours	·87	1·22	1·00
Dissolved Oxygen	·42	·30	38
Oxygen absorbed from $KMnO_4$ in 3 minutes	·10	·25	·19
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

March 22nd, 1904. *Joshua Bolton.*

HEYWOOD.—*continued.*

SEWAGE— March, 1904.

Average Daily flow	1,143,903 gallons.	Month's rainfall	2·34 inches.
Maximum daily flow	2,920,875 „	Rainfall	·62 „
Minimum daily flow	580,125 „	Rainfall	nil

TANKS—

Average daily flow through Tanks	1,143,903 gallon, equals to 14 hours 17 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemical used	10 tons 17 cwts. 3 qrs.
Amount of Sludge dealt with	1,606 tons 14 cwts.

April, 1904.

SEWAGE—

Average daily flow	1,073,333 gallons.	Month's rainfall	1·97 inches
Maximum daily flow	1,959 000 „	Rainfall	31 „
Minimum daily flow	604,875 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	1,073,333 gallons, equal to 15 hours in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	9 tons 15 cwts.
Amount of Sludge dealt with	1,454 tons.

May, 1904.

SEWAGE—

Average daily flow	856,354 gallons.	Month's rainfall	2·93 inches.
Maximum daily flow	1,415,625 „	Rainfall	·32 „
Minimum daily flow	597,000 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	856,354 gallons, equal to 18 hours 49 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	10 tons 15 cwts.
Amount of Sludge dealt with	1,383 tons8 cwts.

June, 1904.

SEWAGE—

Average daily flow	779,800 gallons.	Month's rainfall	1·22 inches
Maximum daily flow	1,449,750 „	Rainfall	·38 „
Minimum daily flow	552,000 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	779,800, equal to 20 hours 84 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	10 tons 15 cwts.
Amount of Sludge dealt with	1,646 tons 15 cwts.

July, 1904.

SEWAGE—

Average daily flow	771,935 gallons.	Month's rainfall	1·64 inches
Maximum daily flow	1,408,125 „	Rainfall	·21 „
Minimum daily flow	562,875 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	771,935 gallons, equal to 21 hours in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	11 tons 1 cwt.
Amount of Sludge dealt with	1,432 tons 5 cwts

HEYWOOD—*continued.*

August, 1904.

SEWAGE—

Average daily flow	948,645 gallons.	Month's rainfall	4·96 inches.
Maximum daily flow	2,629,500 „	Rainfall	1·34
Minimum daily flow	465,000 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	948,645, equal to 16 hours 28 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	10 tons 4 cwts.
Amount of Sludge dealt with	1,203 tons 2 cwts.

September, 1904.

SEWAGE—

Average daily flow	669,000 gallons.	Month's rainfall	1·00 inches
Maximum daily flow	1,119,375 „	Rainfall	·37 „
Minimum daily flow	451,125 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	669,000 gallons, equal to 24 hours 3 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	11 tons 8 cwts.
Amount of Sludge dealt with	1,518 tons 11 cwts.

October, 1904.

SEWAGE—

Average daily flow	772,193 gallons	Month's rainfall	2·03 inches.
Maximum daily flow	2,218,500 „	Rainfall	·72 „
Minimum daily flow	404,250 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	772,193 gallons, equal to 21 hours in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	10 tons 15 cwts.
Amount of Sludge dealt with	1,729 tons 4 cwts.

November, 1904.

SEWAGE—

Average daily flow	1,019,000 gallons.	Month's rainfall	3·50 inches.
Maximum daily flow	2,658,000 „	Rainfall	·97 „
Minimum daily flow	384,375 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	1,019,000 gallons, equal to 15 hours 56 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	10 tons 7 cwts. 1 qr.
Amount of Sludge dealt with	1,605 tons 12 cwts.

December, 1904.

SEWAGE—

Average daily flow	1,142,129 gallons.	Month's rainfall	2·14 inches.
Maximum daily flow	2,698,500 „	Rainfall	·60 „
Minimum daily flow	559,750 „	Rainfall	nil.

TANKS—

Average daily flow through Tanks	1,142,129 gallons, equal to 14 hours 3 minutes in Tanks.
Average number of Tanks in use	5½.
Amount of Chemicals used	9 tons 10 cwts.
Amount of Sludge dealt with	1,565 tons 15 cwts.

Mr. James H. Kershaw, F.C.S., Chemist and Manager of the Corporation Sewage Works, Rotherham, called in; and Examined.

Mr. James H. Kershaw, F.C.S.

10 May 1905.

21390. (*Chairman.*) You are Mr. James H. Kershaw, Fellow of the Chemical Society, chemist and manager of the Corporation Sewage Works, Rotherham?—Yes.

21391. You have come before us to-day to give evidence as to your experience in the treatment of sewage, with special reference to the Rotherham Sewage Works?—Yes.

21392. At Rotherham what is your system of sewage treatment, shortly described?—Sedimentation, followed by single contact, and then passed over land.

21393. What is the population draining to the Rotherham works?—About 53,000 or 54,000.

21394. What is the system of drainage? That is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent?—It is mostly on the combined system. Only to a very small extent is the storm water kept separate from the sewage.

21395. Is there any infiltration of subsoil water into the sewers?—Yes.

21396. What is the water supply per head, and from what source does it come?—The water supply is 23·27 gallons per head. A portion of it is derived from local gathering grounds in an agricultural district, and the rest consists of moorland water, which we get from the Sheffield Corporation.

21397. Is it hard or soft water; if the former, what are its chief mineral ingredients?—The water we get from Sheffield is soft. Our local water is hard. As the hardness is mostly permanent, it will be due chiefly to the presence of sulphate and chlorides of lime and magnesia. A little iron is also present.

21398. What is the drainage area of the part of the town which is sewered?—About 1,000 acres.

21399. What proportion of the population use pail closets or middens and what proportion use water-closets?—The pail system is not used in Rotherham. Water closets are provided for about half the population, and midden closets for the remainder. Last year over 300 midden closets were replaced by water-closets.

21400. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of twenty-four hours in dry weather in winter and in summer?—The flow of sewage has only been gauged when the tanks have been refilled after sludging. The last measurements were made in October, 1904, when the flow was a little over 980,000 gallons in twenty-four hours.

21401. What is the maximum dry weather rate of flow, and at what hour does this occur?—That has not been determined.

21402. Has the minimum dry weather rate of flow been determined?—No.

21403. Can you say what has been the maximum wet weather rate of flow to the works, and during how many hours it has continued?—No.

21404. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation?—There are several fixed sills or weirs in the sewers, but I have no information as to the rate of flow at which they come into operation.

21405. What is the largest number of gallons of sewage which have passed the last storm overflow and come to your works in twenty-four hours?—No observations have been made.

21406. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—Our drainage area is about 1,000 acres, and in 1904 the total rainfall was 20·66 inches. This represents 468,723,750 gallons of water.

21407. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year, and the volume which passes over your overflows?—I should say we received during 1904 at least 365,000,000 gallons of sewage at the works. I have no knowledge as to the volume passing over the overflows in the sewers.

21408. If there be any infiltration of subsoil water into the sewers, does it occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—We get some subsoil water into the sewers, but I am unable to give any idea as to the amount. Some of the sewers are laid in very wet ground. The rate of infiltration will be influenced by the height of the ground water.

21409. How many gallons of trade effluents enter the sewers daily (twenty-four hours), and what is the nature of these effluents? If you have analytical figures, please give them?—The only trade refuse we have traced up to the present comes from one works, and amounts (so I am informed) to between three and four thousand gallons per twenty-four hours. This is a works where gas liquor is dealt with for the recovery of the ammonia it contains. The waste liquors from the still are discharged without any kind of treatment direct into the sewer. This refuse is heavily charged with soluble sulphides and sulphocyanides, etc., and at times the amount of suspended matter present is very considerable. Lime is used in the process to liberate the ammonia. I have examined a few samples of this particular refuse with the following results:—

All the samples gave an alkaline reaction with litmus paper, and had a phenolic odour. Many contained much greyish suspended matter which quickly settled, leaving a very clear, brown top water. The suspended solids consisted very largely of waste limey matter. HCl. added to the samples dissolved practically all the suspended matter, much H_2S being liberated.

	1.	2.	3.	4.
Solids in suspension	Very small amount	2628·0	344·0	2568·0
„ in solution	—	1836·0	180·0	2216·0
Total solids	1138·0	4464·0	524·0	4784·0
Which on ignition lost	290·0	172·0	128·0	748·0
And the ash	848·0	4292·0	396·0	4036·0
Oxygen absorbed—4 hrs. test—at laboratory temperature, by sample as taken	438·0	967·0	71·5	1090·0
Oxygen absorbed—4 hrs. test—by liquid portion only	—	939·78	63·5	1080·0
Sulphocyanides and cyanates, calculated as NH_4SCN	200·0	150·0	25·0	250·0

There were estimated (approximately), colorimetrically, by means of an acid (HCl) solution of Fe_2Cl_6 and standard NH_4SCN.

21410. Has your authority framed any rules for the reception of trade effluents into sewers?—At present we have no rules or regulations dealing with the admission of trade refuse to our sewers.

21411. Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume, or otherwise? If so, would you kindly tell us what your difficulties are?—I have explained the nature of the trade refuse in reply to Question 21409. I find the presence of that trade refuse in the sewage interferes very seriously with our results. It is not the volume so much as the strength or quality of the liquor that causes the trouble. At first when we began to get this refuse at the works many square yards of the surface of our filters were literally covered with worms that were evidently driven out of the material by the presence of something unusual in the tank effluent run on to the beds. These worms appeared to be in a very sickly condition. I allowed them to remain, and the filters were worked as lightly as possible for a few days, when almost the whole of the worms went down into the filter again. A recurrence of this takes place when the liquor comes down with a rush instead of in a steady stream. Our process consists of sedimentation, single contact (in coal filters), and finally the water is passed over heavy clay land. Sulphocyanides are nearly always present in the effluent, and as these compounds react in the oxygen absorption and the albuminoid ammonia tests the samples often come out badly on analysis, although I have never found them to become putrescent or deteriorate on keeping at laboratory temperature. As we do not get regularly satisfactory results with our present plant, I am constructing some experimental filters to ascertain the effect produced by second contact and continuous filtration.

Mr. James H. Kershaw, F.C.S.

10 May 1905.

21412. Can you say what the average amount of suspended matter in your sewage is in dry weather?—I have made no detailed estimations of the suspended matter present in our sewage; but from our two screens (one with three-quarter inch spaces and the other with half inch) and catch pits we remove from twenty-five to thirty one-horse loads of refuse and silt per month.

21413. What is the physical character of these solids?—This stuff consists chiefly of paper, solid excreta, rags, pieces of wood, lumps of grease and fat, vegetable waste, occasionally intestines, etc., from slaughter-houses, and in addition the sandy matter washed into the sewers from the roads. The suspended matter going forward to the tanks will consist of this class of material, only in a more broken up or disintegrated state.

21414. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—The average results of sewage analyses are as follows:—

SUMMER, 1903.

	Oxy. Ab.	NaCl.	No. of Wet Days.	Inches Rain.
June	5·68	17·57	No record.	
July	6·5	19·5		
August	6·44	19·27		
September	7·18	18·9		
Average	6·45	18·81		

WINTER, 1903.

November	4·25	15·98	12·	1·51
December	3·15	14·05	15·	1·13
January	4·80	14·8	No record.	
February	6·43	—		
Average	4·41	14·94		

SUMMER, 1904.

June	6·67	18·89	5·	·34
July	8·19	18·57	9·	1·57
August	8·37	19·44	9·	3·51
September	8·68	20·41	6·	·91
Average	7·98	19·33	Total 29·	Total 6·33

WINTER, 1904.

	Oxy. A.	NaCl.	No. of Wet Days.	Inches Rain.
November	9·6	21·30	11·	·97
December	11·76	—	11·	1·44
January	5·02	14·8	16·	2·13
February	2·95	12·45	19·	3·75
Average	7·33	16·18	Total 57·	Total 8·29

Mr. James H. Kershaw, F.C.S.

10 May 1905.

21415. Is it a "strong" sewage, and, if so, what characterises its strength?—Apart from the trade refuse before referred to, ours is not a strong sewage.

21416. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—The strength of the sewage does not vary very much during the day, but some days it is stronger than others. These variations do not materially affect the final effluent.

21417. Have you any information as to the bacteriological condition of the sewage in dry weather and in storm times?—No.

21418. Are there any chemical poisons in the sewage? If so, what are they, and to what extent do they occur?—Yes. Sulphocyanides are almost always present. I have only recently commenced to estimate the amount present in our sewage, but I have had to do with sewage containing (approximately) sulphocyanides expressed as NH_4SCN, varying from traces up to 110 parts per 100,000.

21419. Is the sewage always alkaline?—Up to the present it has always been either neutral or faintly alkaline. I have never known it acid.

21420. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—The amount of suspended matter in sewage is very largely increased in times of storm.

21421. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—Our main system of sewers is practically new, having only been down six or eight years. One section at least of the old system of sewers which is at present in use has sunk to some extent, so that an accumulation of solid matter takes place.

21422. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—The following results were obtained from the partial analysis of samples taken during storms at overflows. As taken the samples were offensive, and contained much solid excreta. After removing the suspended matter by passing once through filter paper, the liquids were all fairly clear and not particularly offensive.

—	As taken.					After removing suspended matter.				
	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)
Chlorine as NaCl	—	—	—	—	—	5·6	3·3	3·9	—	—
Free NH_3	1·12	—	1·44	1·08	1·16	1·17	1·12	1·12	—	—
Alb. do.	1·03	·76	·66	·98	1·08	·141	·14	·16	·13	·1
Oxygen absorbed (4 hours test)	8·13	5·6	—	—	—	1·37	1·41	—	—	—

Purification effected by removing the suspended matter: On the Alb. NH_3, 86%, 81%, 75%, 86%, 87%; on the oxy. absorbed, 83% 74%.

21423. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely-increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—The sewage is very foul for some considerable time after a storm arises. The damage likely to occur from choking of filters by passing storm sewage through the ordinary dry weather plant depends largely on the circumstances of the case. For instance, if the tanks are clean and contain comparatively little sludge, little or no harm should take place; but if, on the other hand, the tanks are dirty and about ready for sludging when the storm takes place, the extra rush and speed of the water through the tanks will set the sludge in motion, and a great quantity will be washed out and carried into the filters, thus causing choking up to take place. The method suggested in the latter portion of the question for settling the whole of the storm sewage in tanks would no doubt be very helpful and useful, but I am afraid such treatment alone, without some form of subsequent filtration, could not be relied upon to produce a satisfactory effluent.

21424. Do you think that the point at which storm overflows should come into operation should depend upon the configuration of the land—whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—In hilly districts the storm sewage will pass away to the outfall works more rapidly than in flat districts, so that storm overflows might be allowed to come into operation sooner in the former than in the latter case.

21425. Should storm overflows be fixed or movable?—In my opinion storm overflows should be fixed.

21426. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight while in others this would not be the case?—Storm sewage discharged after the same number of dilutions would not have the same effect on all streams. If the overflow is into a large stream a smaller number of dilutions might be allowed before the discharge takes place than if it was run into a small stream.

21427. Could you give us an analysis of a typical sample of your road water during the early period of a storm?—No.

21428. Have you any information as to the bacteriological condition of the road water?—No.

21429. Do you consider that in certain circumstances this liquid should be purified?—Yes.

21430. What are your views as to the comparative cost and advantages of the separate and combined system of sewers?—I have no information on this matter.

21431. Is your sewage settled, and, if so, how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—

Our sewage is settled on the continuous system, and takes about a day to pass through the tanks. The average tank effluent for 1904 took up 3·65 parts oxygen and contained 14·33 NaCl., and showed a purification over the sewage of 49·37 per cent. on the oxygen absorption.

21432. Have you data to show what proportion of the suspended matter in your sewage is settled in half-hour, one, two, three, four, five, six, twelve, and twenty-four hours, if the sewage is given quiescent settlement?—No.

21433. What time would be necessary for you to gain a good tank liquor containing, say, no more than six or eight parts of suspended solids per 100,000 from your sewage (without the addition of chemicals), by quiescent settlement and by continuous flow settlement?—That has not been determined.

21434. Do you prefer to use settlement tanks in series or in parallel?—I should say tanks used in series will give best results.

21435. In the case of continuous flow tanks do you think there is any advantage in the employment of baffling boards or walls?—I do not think baffle walls are of much service, but scum boards should be provided.

21436. How is the *sludging* of tanks done at your works, and what is the character of the sludge? Does any nuisance attend the operation, and, if so, is it serious? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from your tanks?—All the sludge from our tanks gravitates to a well inside the building, from which it is lifted by ram pumps into an overhead tank outside, then, if we wanted to press, it would flow back into the mixing vessel, and after liming, etc., it would go to the presses. Up to the present it has all been run from the overhead tank into lagoons. Whenever you have several thousand gallons of liquid sludge exposed there is bound to be some amount of smell, but at no time has there ever been anything that could be called a nuisance. We have no storage. The sludge has all to be got rid of at once.

21437. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—I prefer to keep the road detritus out of the tanks as much as possible.

21438. What is the manurial value of your sludge, and will farmers take it?—For some reason or other farmers seem to have a dislike to sewage sludge as a manure. There is much difficulty in getting them to give it a fair trial. We were fortunate last year in having a fair quantity taken away. Spread on our own grass land it improved the herbage very considerably. Potatoes also did well with it. An average sample of sludge being pumped into our lagoons in January gave the following results:—

H_2O - - - - -	85·0	per cent.
Organic and volatile matter -	7·4	,,
Mineral and sandy matter -	7·6	,,
	100·0	

Another sample of sludge after drying in a shed for a considerable time contained

Moisture - - - -	12·77	per cent.
Organic and volatile matter -	25·82	,,
Sand and mineral matter -	61·41	,,
	100·00	

Owing to the ready solubility of ammonia salts, the amounts found in sewage sludge are usually very small indeed. In my opinion very much less difficulty would be met with in the disposal of the sludge produced at many works if it could be reduced to the form of a coarse powder at anything like a cheap rate. In this condition it would be more convenient to handle and use, and probably these advantages would induce a more general desire to give it an extended trial.

21439. Are there any chemical poisons in the sludge?—I do not know of any.

21440. Do you find any nuisance from the treatment of sewage in settlement tanks? Have any complaints been made?—We get a slight smell from the tanks at times, but nothing serious. No complaints have been made.

21441. Have you had experience of the chemical precipitation of sewage?—Yes.

21442. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—No.

21443. Have you tried various chemicals? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—I am not able to give comparative data as to cost, etc., as my experience was with one particular process.

21444. What is the most effective way of adding chemicals?—The chemicals should be in solution before being added to the sewage.

21445. What is the character of the suspended matter in the liquor from the precipitation tanks?—The small amount of suspended matter present in the tank effluent would most likely consist chiefly of $Al_2(OH)_6$ and probably insoluble compounds of fatty acids derived from soap.

21446. Do you find it necessary to add further chemicals to the sludge before it can be dealt with? If so, for what reasons, and how are they added?—If sludge is to be pressed at anything like an economical rate it is absolutely necessary to mix lime with it. When sludge is pressed without lime it is very seldom that above two charges of good cake can be drawn from a press in one day, whereas when lime is used a press may be charged and drawn in about an hour. The lime helps to hold the water, and at the same time produces a hard, dry-looking cake. It is best to add the lime in the form of a fine dry powder to the liquid sludge in the mixing vessel before it passes into the forcing rams. However hard and dry a piece of fresh press cake may look and feel, it almost always will contain 50 per cent. or more of water.

21447. What was the manurial value of the sludge obtained by the chemical precipitation of sewage, and would farmers take it?—The sludge resulting from the precipitation process (with which I was at one time connected) after drying, etc., was sold. As there was a good demand for it I presume its manurial value in practice was found to be satisfactory.

21448. Did it contain any chemical poisons?—Not to my knowledge.

21449. Did you find any nuisance from the treatment of sewage in chemical precipitation tanks? Were any complaints made?—Under normal conditions no nuisance need be caused by precipitation tanks.

21450. As regards septic tanks, how should they be shaped?—An oblong tank and not too narrow seems to me to be the best shape, and arranged so that the sewage flows in the direction of the greatest length.

21451. Should they be divided into sections?—I do not think it is necessary to divide tanks into sections unless it is for the purpose of facilitating sludging.

21452. Should they be used in series or in parallel?—In my opinion it is better to use tanks in series than in parallel.

21453. Is a scum necessary or desirable?—I do not think a scum is absolutely necessary.

21454. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—In my opinion no material benefit is to be derived by having the tank closed.

21455. What do you consider the best arrangement for the "feed" and "draw-off"?—I consider some form of submerged inlet and outlet desirable in order to prevent a mere surface flow.

21456. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—As much as possible of the suspended matter should be removed from sewage before it is applied to filters.

21457. In what way do you consider that the removal of the suspended solids can best be effected?—In order to get the sewage as free as possible from suspended matter it is essential that plenty of tank accommoda-

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tion be provided ; also that the flow should be steady. The tanks should be kept clean, *i.e.*, they should be emptied of sludge at frequent intervals.

21458. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?—No.

21459. What other (if any) method of dealing with tank liquor before delivering it to filters do you regard as necessary or desirable?—If the conditions mentioned in reply to Question 21457 are fulfilled, a very good tank effluent would result, and it would not be necessary to treat it further before applying it to filters.

21460. As regards contact beds, is it advisable to construct the whole or any part of the interior of building material, or may you in some cases dispense with it entirely?—When the land is of a clay or stiff nature the only building material required in making contact beds is that used in the construction of the valve chamber. For making capacity measurements it is, of course, necessary that the filter material should be contained in a watertight enclosure ; in such cases building material is necessary.

21461. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—My experience has been with beds 3 ft. to 4 ft. deep. These give good results. I do not see why the efficiency should vary materially with beds of greater depth. The actual depth would be decided by the conditions and circumstances of the case.

21462. What do you consider is the most convenient size for a contact bed?—I consider that contact beds should be of such a size that they can be filled in one hour or less.

21463. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is, in your experience, the least disintegrable in a contact bed?—My experience has been with beds filled with coal. This has done good work, and after nearly three years' working shows little signs of disintegration. Clean, well-burnt clinker is, in my opinion, as good as anything that can be used for filters. I am at present filling a bed with furnace coke, which I believe will prove a useful material. In certain districts "saggers" and other pottery waste would be available, and would do well in filters.

21464. What size should the filtering material be, and should it be graded in the beds?—Assuming tank effluent is to be dealt with, the body of a first contact bed might be filled with material passing through a 1¼ in. screen and retained on a 1 in. screen. For second contact, material from ⅝ in. to ⅛ in. could be used. I think it is advisable to have a layer of fine material (but free from dust) on the top, so that as much as possible of any suspended matter may be kept out of the body of the bed, and so that it can be removed at intervals, if necessary ; also that it may be exposed to the action of the atmosphere and the larger forms of low life.

21465. How should the bottom of the bed be constructed?—The floor of a contact bed should be fairly smooth or even, and should have a fall from every part to the outlet valve. Perforated pipes or draining tiles should be arranged at intervals over the floor, and the whole covered with a layer of rough material to carry the smaller material used in the body of the bed.

21466. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—It is very necessary that sewage should go through some form of tank treatment before it is put on contact beds. Otherwise they will choke up rapidly.

21467. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary beds and for secondary beds?—I consider three fillings per day (worked in cycles of eight hours) is enough work to put on contact beds, and that there should be one hour for filling, two hours standing full, one hour emptying, and four hours' rest. No material benefit appears to be produced by a much longer contact than two hours.

21468. How should contact beds be filled and emptied?—I have not observed any difference in the results obtained from filters filled by means of half pipes laid on the surface of the material and others where the water has been run direct on to the material. If circumstances permitted, I would like to see the effect produced by filling a contact bed by means of a spray or sprinkler, with the idea of getting the water well aerated before it gets into the bed. In emptying, I think it best to start steadily till about a foot or so has run off, when the valve should be opened to the full extent and kept open till the filter is filled again.

21469. Have you had any experience of automatic gear for filling and emptying contact beds?—I have no personal experience of automatic gear for filling and emptying filters.

21470. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent? If so, please state in precise terms (*i.e.*, by analytical figures) of what tank liquors you are speaking and what effluent you are regarding as satisfactory?—Single contact cannot be relied upon to regularly produce satisfactory results. In 1903 the average oxygen absorbed by the tank effluent was 2·34, whilst the filtrates from single contact absorbed ·96 parts of oxygen, the purification effected being 59 per cent. In 1904 the tank effluent absorbed 3·65 parts of oxygen and the filtrates 1·49, the purification being 59·18 per cent.

21471. Is the loss of capacity in contact beds in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed, or to the fineness or coarseness of the material of the bed, or on what does it depend?—I should say the loss of capacity is in proportion to the volume of the liquid treated and the amount of suspended matter it contains. The quality of the suspended matter must also have some influence, for if it consists of inorganic or sandy matter it will remain permanently in the bed, and tend to choke it unless it passes out in the effluent. There is less danger of choking permanently from the organic portion of the suspended matter when left in the bed. In this case there is the possibility of the organic matter being broken up and consumed, to some extent at least, by biological and other means, thus causing a diminution in its bulk, and consequently lessening its power to diminish the water capacity. Then the grade of the material must have much to do with the loss of capacity. It is obvious that a filter made of fine material will remove more suspended matter from a given liquid than one made of coarser material, and the more suspended matter left in the bed the greater the loss in its water capacity.

21472. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard?—I have had no experience of washing the material from a filter, but I should say it is possible.

21473. How can the capacity of contact beds be best maintained?—The water capacity of filters is best maintained by (a) feeding them with a liquid as free as possible from suspended matter ; (b) not overworking them ; (c) thorough draining off ; (d) giving them a complete rest as often as possible ; (e) when the surface of the bed requires loosening or forking over, it should be done carefully, as it must tend to disintegrate the material to some extent.

21474. What is the average analyses of your single contact and double contact effluents?—We have only single contact. The average filtrates for 1903 and 1904 were as follows :—

	No. of samples.	Oxygen absorbed.	NaCl.
1903	175	·96	13·09
1904	153	1·49	14·6

21475. What is the number of gallons of liquid treated daily per cubic yard of filtering material in your beds?—Last year the average daily amount of liquid treated per cubic yard of material would be about 82·6 gallons by our single contact beds.

21476. Do you find any chemical poisons in the final effluent?—Sulphocyanides are usually present.

21477. What is the average amount of suspended matter in the effluent? Does most of this suspended matter come out with the first flush or not?—The amount of suspended matter in the filtrates has not been determined. The first flush usually contains

most of the suspended matter, but the drainings contain some. The bulk of the discharge is very free from suspended matter.

21478. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed is different from the organic matter of the suspended solids going on to that bed?—No observations have been made on this point. The suspended matter from our filter appears to contain some gritty matter, but the bulk of it consists of a dark-coloured growth, which I believe collects in the drain pipes in the beds.

21479. Is the first flush of effluent from the beds ever putrescible?—This has not been determined.

21480. Do you find that by increasing the number of fillings in storm times or other times the amount of suspended solids is increased?—No material visible increase has been noticed.

21481. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency?—I have no experience of using contact beds as streaming filters in storm times.

21482. Have you made any experiments which throw light upon the action of contact beds when full and when resting?—No.

21483. Have you made a study of the conditions of aeration of contact beds?—No.

21484. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—There has been no nuisance arising from the working of our contact beds. No complaints have been made.

21485. Have you had any experience of continuous or percolating filters?—I have two filters, each 50ft. diameter and 4ft. 6in. deep, fed by revolving sprinklers, but as they have only been working a few weeks my experience is too short to enable any decided opinions to be expressed on the working, etc., of this type of filter. The filtering material is coal. Open septic tanks precede the filters. I will give the results obtained up to the present from these filters. The filtrates were examined after the suspended matter had been removed. Samples were then bright and clear, and had a fresh, earthy odour. The analyses are as follows:—

Tank Effluents. Oxygen absorbed.	Filtrates. Oxygen absorbed.	Nitric N.	Purification.
5·4	2·45	—	54·6 per cent.
6·25	·8	·028	87·2 „
9·11	1·66	—	81·7 „
7·0	1·06	—	84·8 „
7·48	1·46	—	80·4 „
5·1	1·24	·233	75·7 „
3·58	·83	·908	76·8 „
6·65	1·34	—	79·8 „
—	1·13	·25	—
Average = 6·32	1·33	—	77·6 „

21486. Do you find that the chance of nuisance is any greater with one form of filter than with another? Does the risk of nuisance depend on the kind of sewage which is being treated or on the nature of the preliminary treatment to which the sewage has been subjected?—I should say filters fed by means of jets, sprays, or sprinklers are more likely to cause a nuisance than contact beds fed in the ordinary manner. The risk of nuisance depends to a very large extent on the preliminary treatment the sewage has been subjected to. For instance, strongly septic tank effluents when sprayed or sprinkled will most likely give rise to some amount of nuisance. Our contact beds are fed with open septic or sedimentation tank effluent. I have found no nuisance from them.

21487. Could you express an opinion as to how the number of gallons would vary with variations in the strength of your tank liquor, and on what figure or figures you would rely for defining the "strength" of your tank liquor?—Taking the oxygen absorbed as the standard of strength, I have found that our beds will bring about a purification usually of from 50 to 60 per cent. in the tank effluent run on.

21488. Have you had any experience of storm water filters?—No.

21489. Can you express any opinion as to whether storm water filters would lose any of their efficiency by being used intermittently at long intervals?—Judged from the experience of getting contact beds into condition at first, I should say that storm filters cannot be regarded as anything but strainers if used at long intervals, and if the dilution required by the Local Government Board is insisted upon, very little more than straining should be required.

21490. Have you any practical suggestions to make for disposing of sludges?—As regards sewage screenings, seeing that the greater portion of the material removed from the screens at sewage works consists of organic matter, the most effective method of disposal is by burning in some kind of destructor, or the stuff may be tipped and covered with earth so as to prevent nuisance. The material from detritus tanks consisting of sand and gritty matter does very well for lightening heavy land, otherwise it can be tipped, when by exposure it rapidly gets purified, losing its offensive black colour and becoming like ordinary road grit. Sludge from precipitation, septic, and settlement tanks is best pressed in order to keep the bulk within reasonable limits. As much as possible of all forms of sludge should be disposed of to farmers. In some cases it might be admissible to drain the sludge in lagoons instead of pressing.

21491. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?—Press cake and sludge containing lime, when tipped in a heap, is very liable to heat, and becomes a nuisance owing to the peculiar sickly odour it gives off. Lagoons are usually strongly condemned, but up to the present all our sludge has been disposed of by this method without nuisance.

21492. What, in your opinion, constitutes a good effluent?—A good effluent is one in my opinion which is not offensive in appearance or smell, and is not liable to become, when discharged into a stream, changed in appearance or smell. Nitrates should be present, and it should not yield more than from ·1 to ·15 parts Alb. NH_3 per 100,000, nor absorb more than 1 to 1·5 parts oxygen in the four hours' test. It should

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not become putrescent or offensive on keeping, and it should be free from suspended matter.

21493. Do you consider the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—I cannot express a definite opinion on this point, as I have only been using continuous filters for a short time. Percolating filters appear to produce better nitrification than single contact beds.

21494. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—As a routine test I always use the four hours' oxygen absorption test at laboratory temperature, because of its easy application, and as I find that if our outfall samples come out satisfactorily to this test they never deteriorate or become putrescent on keeping. Nitrate and alb. ammonia determinations are also made from time to time.

21495. Have you tried the "aeration" test, *i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—I have not as yet used the "aeration test."

21496. Is one standard for all effluents passing into non-potable streams possible and desirable?—I do not think it practicable or desirable that one standard should be fixed for all effluents passing into non-potable streams.

21497. How should a plurality or series of standards be formulated? What amount of suspended matter would you allow in an effluent, and what are your reasons?—As one general standard is not considered desirable, I should say a combined standard of, say, 1·5 parts alb. NH_3, or 1·5 parts oxygen absorbed four hours in addition to the presence of nitrates might be found equitable. It is a difficult matter to keep effluents entirely free from suspended matter, but I should say 2 or 3 parts per 100,000 might be allowed.

21498. What is your experience of the effect of storm water upon filters of various sorts?—I have not noticed any special effect produced by storm water on our contact beds beyond the danger there is of carrying more suspended matter out of the tanks on to the beds owing to the increased rate of flow.

21499. How far do you consider it advisable for a sewage installation to be worked automatically?—No sewage installation of any dimensions should be worked automatically. Private residences and small villages might be so worked if seen every day, but installations for 500 population and upwards should receive constant attention. The greater the attention the better the effluent, and the less liability to nuisance.

21500. Have you made any systematic observations as to the effects of discharging effluents of known volume and known composition into ditches, canals, brooks, or rivers of approximately known volume? The main points I refer to are nuisances from smell, deoxygenation of the water, encouragement of vegetable growths either of the nature of sewage fungus or of green weeds, and damage to fish?—After examining a large number of samples from our single contact beds it was found that they could not be relied upon to produce a filtrate requiring not more than one part of oxygen in the four hours' test, but the further observation was made that, on these samples being re-examined after keeping a few days, a very marked improvement was almost always found to have taken place. This may, in my opinion, be due chiefly to two probable causes—firstly, a continuation of the biological action commenced in the filter and continued by the organisms carried out of the bed and present in the filtrate; or, secondly, the improvement may be due to the method we use for emptying the filter, viz., by means of a compressed air lift. A very large volume of air is thoroughly incorporated with the water, and possibly a sufficient amount of oxygen may pass into solution to bring about wholly or in part the diminution in the amount of oxygen required in the absorption test applied after the samples have stood some time. This is a point I hope to go into as soon as circumstances allow. We have several depressions on our land which always stood full of water even before the works commenced. With the object of utilizing the above observation I decided to make use of these ponds for the further purification of a portion of our single contact water. They were connected together by means of ditches; in places the water was made to spread out and flow in a thin sheet, so as to get as much exposure as possible. Altogether, we shall have an area of six to eight acres of water regularly exposed in these ponds. A public footpath runs through the largest one, connecting pipes having had to be laid. The water from this pond goes direct to the outfall. I never intended using the ponds as much as they have been, but as a considerable improvement was effected their use was continued. Largely owing to this arrangement, we were enabled to do without a night shift of men for quite twelve months. On an average about 150,000 gallons per day would be passed through the ponds, the outlet being always open and continuous, Owing to the publicity of the site great care had to be used in the working. I found the weather had a great influence over the water in its appearance. With regard to the question of nuisance, unless the thing is very carefully watched and worked there is undoubtedly a danger of a nuisance arising. At times there has been a distinct vegetable or sea-weedy odour, but it has never amounted to a nuisance. No determinations of dissolved oxygen have been made, but the use of this test is about to be adopted. When the ponds have been worked too hard or fed with bad water I have often noticed sewage fungus begin to grow. This disappears with resting. Normally a large amount of a green weed grows, and sometimes the whole surface of the water will be covered in places with it. There are no fish in the ponds. I find that this method of treatment brings about a reduction of at least 50 per cent. in the oxygen absorption figure. Very little nitrification appears to take place. I do not advocate the use of ponds, but as additional filters were not obtainable the natural features of the site were used in what appeared likely to prove a useful manner.

21501. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—I think the results of the four hours' oxygen absorption and the alb. ammonia determinations are the two most useful items to have in order to form an idea as to the strength of sewages, etc.

21502. Are there any other points on which you would wish to speak at this stage?—I should like to make some observations on the effect of keeping samples of effluents. It is a matter of common knowledge that many samples of effluents develop a green growth on keeping. This is taken as a rough indication that the sample is of good quality. In order that this green growth may develop it is essential that the sample be exposed to the light. I have taken fresh samples of effluents, and, after dividing, put one in a dark cupboard and allowed the other to be freely exposed to the light. In no case has the dark sample (in one instance samples were kept 225 days) developed the growth, but in the other it has nearly always shown itself. It has also been noticed that this growth may develop rapidly. In one case I found it to be very distinct in five hours after the sample had been put into the bottle. If the bottle stands near a window I have found that the growth develops first and attaches itself to the side of the bottle next the window. This development goes on till the whole contents of the bottle become quite muddy with the green suspended matter. Usually a "sea-weedy" odour is developed at the same time. In addition to the above I have observed for a long time that this green growth when pretty strongly developed is always accompanied by the production of an alkaline reaction in the sample. From inquiries made, I believe this is the first occasion on which this observation has been noted. I have never found a sample to develop this alkalinity in the absence of the green growth, consequently samples kept in the dark do not turn alkaline. The alkalinity is most readily shown by adding a few drops of phenolphthalein to the "green sample," when if the alkali is present the liquid turns red or pink, according to the amount present. I have not yet proved what this is due to, but that it consists of a volatile alkali (ammonia?) at least to some extent the following experiments will show:—Three samples were taken from a large number, all more or less green, and 100 c.c. of each were titrated with deci H_2SO_4 to Phenolphthalein (P.T.); then methyl orange was added, and the titration continued till just acid. A further 100 c.c. of each sample was then evaporated to dryness. The residue was taken up with fresh distilled water of proved neutrality, and titrated as before.

100 c.cs. taken.	1.	2.	3.
Age of Sample in days	55	49	17
C.c.s. $\frac{\text{deci.}}{H_2SO}$ required to P.T.	1·2	1·4	·8
Then do. more required to M.O.	1·2	1·2	2·8
C.c. $\frac{\text{deci.}}{H_2SO_4}$ required by total alkali	2·4	2·6	3·6

100 c.cs. after evaporation.	1.	2.	3.
C.c.s. $\frac{\text{deci}}{H_2SO_4}$ required to P.T.	¼ drop	Nil	1 drop
Then do. more required to M.O.	1·2	1·2	1·2
C.c. $\frac{\text{deci}}{H_2SO_4}$ required by the "non-volatile" alkali	1·2	1·2	1·2

It seems rather remarkable that the non-volatile alkali should show the same amount in samples taken so widely apart. As to what the precise action is, or how this alkalinity is brought about, I am unable at present to explain. I should also like to make some observations on the disappearance of sulphocyanides in sewage on keeping. Having at one time to deal with a sewage which was liable to be irregularly charged with waste gas liquors, a large number of samples were examined. On one occasion sulphocyanides equal to 110 parts NH_4SCN per 100,000 were found to be present in the sewage on its arrival at the works. Some of these samples were kept under notice for long periods, and the following observations made:

Sample.	NH_4 SCN present.	All sulphocyanides disappeared on keeping.	Had sample developed a green growth?
Sewage 1	7·3	19 days	Yes
,, 2	3·4	65 ,,	Yes
,, 3	29·	173 ,,	No
,, 4	52·5	192 ,,	Yes
,, 5	4·	191 ,,	No
,, 6*	12·	161 ,,	No

Sulphocyanides when present in sewage will disappear on keeping, providing a sufficient length of time is allowed. A green growth usually develops, and also an alkaline reaction, but this is not an essential factor in the change that takes place. In my opinion, the most probable explanation of this action is that the change is brought about by biological agency. There appears to be no regularity or fixed rate at which this disappearance takes place. This may probably be due to the difference in the biological contents of the various samples. In order to deal efficiently with sewage mixed with this class of refuse, it is most important that it should be admitted to the sewer in a steady stream, and never in large volumes at one time. It is known that contact beds in good condition are capable of breaking up these compounds to a considerable extent. Experiments are about to be commenced to ascertain the effect produced by treating a liquid containing sulphocyanides on a percolating filter.

21503. On Question 21423 I am not quite sure from your answer whether or not you think it advisable as a general rule that storm sewage should pass through the ordinary plant?—It has to do so at our place; we have to pass it through at our works.

21504. But do you think it is objectionable?—It is sometimes, as I state in my reply here.

21505. Now, with regard to Question 21431. Can you tell me how many parts of suspended solids per hundred thousand you get in your tank effluent?—I cannot; I have never estimated it.

21506. (*Colonel Harding.*) In question 21422 you speak about the character of the storm waters, and you say that the impurities are largely due to suspended matter?—Yes.

21507. And you give an interesting table, from which it appears that the withdrawal of suspended matter from storm waters gives by itself a purification of from 75 to 87 per cent.?—Yes.

21508. Later on, in your answer to Question 21423 you express the opinion that sedimentation of storm water alone without some sort of subsequent filtration could not be relied upon to produce a satisfactory effluent?—Yes.

21509. But a purification of 87 per cent., leaving a liquid which itself is very dilute, does not seem to require very much additional treatment beyond the sedimentation?—No, it does not.

21510. But you think it would be better for some additional treatment?—You see, when these particular samples were taken the storm might have been on for some considerable period.

21511. Arguing simply on the facts you have put before us, it appears that the albuminoid ammonia after sedimentation of these storm waters is represented by only 1·3 per hundred thousand?—Yes. It should not require very much more besides sedimentation, but I do not think sedimentation alone is really satisfactory. I do not think it can be relied upon to produce a regularly satisfactory result.

* No diminution took place after keeping for 89 days and there was no green growth formed. At this point sample was divided (*a*) and (*b*). Some "green growth" from another sample was put into (*b*) and allowed to stand. On keeping 72 days longer I found that (*a* contained only a mere trace of sulphocyanide and that (*b*) was quite free.

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21512. It would give very good results, though not in your opinion thoroughly satisfactory?—Yes.

21513. What additional process would you suggest besides sedimentation?—I have never worked any storm filter, but I should think single contact.

21514. You have no experience?—We have no storm filters; no.

21515. I rather gathered that from your first answer to the Chairman when you said you have not any percolating filters at all?—That is so.

21516. But do you not at Question 21485 make some reference to percolating filters?—I can explain that.

21517. You say: "I have two filters, each 50 ft. diameter and 5 ft. deep"?—We have two works. We have one at a little village about four miles from our main works. We started it only two or three months ago. I was referring to our main works.

21518. Then you have some personal experience of percolating filters?—Very slight.

21519. These two filters have been working for so short a time that you feel that you ought not to say much about it?—I would not like to say much on that point.

21520. The analyses which you have given us were after the withdrawal of suspended matter from the filtrates?—That is so.

21521. Can you tell us how much suspended matter goes on to the filters?—I cannot.

21522. We gather that you have not long been appointed to these works, and have not as yet had time to get into full routine, but appreciate the importance of noting the amount of suspended matter?—Yes.

21523. In Question 21502 you touch upon an interesting point, and that is that the development of green growths in the samples kept in bottles is dependent upon the presence of light?—Yes.

21524. Probably your experience of percolating filters has scarcely been long enough to enable you to tell us whether you have any trouble with fungoid growths on the surface of your percolating beds?—I do not think we have had any fungoid growths, but we have had the thing clogged up with suspended matter.

21525. Are you sure that it was suspended matter only?—Largely.

21526. You have not been able to judge whether it was not to some extent fungoid growth?—I have not examined it closely for that. I was satisfied that it was really the sludge.

21527. It might be worth your while to look into that, and to see whether the development of that growth was dependent upon the action of light. It would be an interesting experiment for you as you appear to be interested on this particular point, to cover a part of the percolating bed—to put a little roof over it or something of that kind to keep the light away—and see whether the development of the fungoid growth, like the green growth to which you call attention, is really dependent upon the presence of light?—Yes.

21527*. (*Dr. Stafford.*) In Question 21474 the difference between your analyses for 1903 and 1904 of the oxygen absorbed test seems very large; what is the explanation?—The only explanation I can give is that we had more sewage connected up—more connections had been picked up during the intervening period.

21528. That makes the difference, you think, in the particular samples?—I should think so.

21529. The difference is very large?—Those are the averages for the whole year.

21530. But you are comparing 1903 and 1904?—Yes.

21531. And the difference is between ·96 and 1·49—a very great difference?—That is the only thing I can put it down to—that we had a stronger sewage to deal with.

21532. (*Major-General Carey.*) Your dry weather flow, based on the water supplied, amounts to 1,232,250 gallons per diem, does it not?—I believe it is somewhere about that.

21533. In October, 1904, your flow was a little over 980,000 gallons, or only 18 gallons a head. Is there any reason for that reduction?—The reason is that we were not getting it all down to the works; a part of it was going to the river direct.

21534. I do not quite understand?—Some of the crude sewage that we ought to have got at the works was not coming to the works.

21535. Is the capacity of your precipitation tanks and contact bed based upon the larger volume?—No, it is on a million gallons per day; it is an approximation to a million gallons per day.

21536. Your tank capacity?—The tank capacity is 900,000. There are six tanks with a capacity of 150,000 gallons each.

21537. Are you able to pass three times the dry weather flow?—As a matter of fact we pass pretty well everything that comes down to the works in storm times through the tanks.

21538. I mean, are you able to pass three times the dry weather flow through the tanks and then on to the contact beds without injury to the bed?—We do it, but I do not think it is an advisable thing, because you are bound to have much more suspended matter washed out of your tanks on to the beds.

21539. How do you treat the remainder?—If it is a very big storm we run it direct on to the land.

21540. How much land have you?—I think, roughly, there are about 10 acres that we can get it on.

21541. But how much land have you altogether?—We have 90 acres in the plot altogether, but we cannot use all that for filtration purposes owing to the formation of the place. There is very little underdraining, and it is very heavy clay soil.

21542. Throughout?—Yes; it can hardly be reckoned to do it any good except by exposure.

21543. Do I understand that all over three times the dry weather flow is put on to this land?—No.

21544. Do you put it on the storm beds?—No, we have no storm beds.

21545. How do you treat it?—We send everything through the tank unless it is a very heavy storm, when we pass some on to the land direct. We do not measure it in any way.

21546. Do you not measure how much you pass on to the contact beds and how much on to the land?—No.

21547. As I understand, the effluent from your contact bed has not been satisfactory?—It is very good for a single contact effluent.

21548. But it would not pass the Mersey and Irwell standard, for intance?—Not regularly.

21549. Are your replies to Questions 21450 to 21455 based upon actual experience in septic tank treatment?—No; that is a general opinion that I hold.

21550. Have you had any real experience of septic tank treatment?—No, I cannot say that I have.

21551. (*Sir William Ramsay.*) In your answer to Question 21411 you say that sulphocyanides are nearly always present in the effluent. Have you estimated the amount of sulphocyanides in the effluent?—Yes, in answer to Question 21418.

21552. You say you have only recently commenced to estimate the amount in the sewage, and that you have had to do with sewage containing approximately sulphocyanides up to 110 parts per hundred thousand. Have you ever estimated it in the effluent?—Not at Rotherham.

21553. Is it your impression that much comes through; is it reduced at all by the filtration process?—I think it is. That is by comparative tests, not actual determination.

21554. Your opinion is that it is reduced by filtration?—Yes.

21555. I do not know whether you have been asked about the order in which you prefer to use settlement tanks. You say that you think tanks used in series give the best results, have you any reason for that opinion?—I have not worked the quiescent system. That is a general opinion I hold.

21556. When you speak of the smell from the tanks as being nothing serious, are there any houses near?—There are only the workmen's cottages.

21557. And they are not likely to complain?—Of course not. I would like to add that we have remark-

ably little smell—nothing you could really complain of. We have two public footpaths across the works.

21558. But the people who cross those paths do not complain?—Not that I know of.

21559. In answer to Question 21467 you say that no material benefit appears to be produced by a much longer contact than two hours on the contact beds. Is that the result of your experience? Have you experimental data to support that?—I have no regular series of analyses, but we have tried it; sometimes the beds have been held up for two, three, or four hours.

21560. But you do not think there is any material benefit in a longer contract?—I have not noticed any.

Mr. James H. Kershaw, F.C.S.

10 May 1905.

21561. Then, in answer to Question 21500 you speak of ponds which were connected all together by means of ditches. Are they deep ponds or shallow?—They are rather shallow.

21562. About what depth?—I do not think they are more than three or four feet at the deepest parts. They are just natural hollows in the land.

ROTHERHAM.

Appendix to Evidence of Mr. James H. Kershaw.

Tables showing average analyses of sewage, tank liquor, filter effluents, and land effluents, January, 1903—December, 1904.

PROCESS OF TREATMENT:

Sedimentation Tanks, Single Contact Beds, and Land.

ROTHERHAM.

SEWAGE.— January, 1903.

Average daily flow - - Rainfall - - - -
Maximum daily flow - - Rainfall - - - -
Minimum daily flow - - Rainfall - - - -

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours, pts. per 100,000	1·91	8·3	4·8
Chlorides as Sodic Chloride	—	—	14·8
Suspended Solids	—	—	—

Number of samples analysed for the average = 22.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - - nil.
Average daily flow through the Tanks - - - - - - - —
Average number of Tanks in use - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·47	5·85	1·87
Chlorides as Sodic Chloride	—	—	11·53
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS.—

Number of Filter fillings during month - - - - - - - 50
Amount of Tank Liquor treated per cube yard per 24 hours - - - —

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·12	1·21	·51
Chlorides as NaCl	—	—	11·53
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·06	·99	·44
Chlorides as NaCl	—		28·1
Suspended Solids	—	—	—

Number of samples analysed for the average = 35.
Purification from Sewage to Outfall = 90·8 per cent.

May 12th, 1903. *Jas. H. Kershaw, F.C.S.*, Chemist and Manager.

ROTHERHAM—*continued.*

SEWAGE.— February, 1903.

Average daily flow - - - —— - Rainfall - - - - - - ——
Maximum daily flow - - —— - Rainfall - - - - - - ——
Minimum daily flow - - —— - Rainfall - - - - - - ——

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours, parts per 100,000	1·27	7·94	6·43
Chlorides as NaCl	—	—	8·9
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - - —
Average number of Tanks in use - - - - - - - - 6.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·48	7·2	2·47
Chlorides as NaCl	—	—	7·82
Suspended Solids	—	—	—

Number of samples analysed for the average = 13.

FILTERS.—

Number of times Filters were filled during month - - - - - 65
Amount of Tank Liquor treated per cube yard per 24 hours - - - —

Average Analysis of Filter Effluent.

——	Best	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·3	1·16	·69
Chlorides as NaCl	—	—	8·65
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·18	1·32	·66
Chlorides as NaCl	—	—	14·0
Suspended Solids	—	—	—

Number of samples analysed for the average = 36.
Purification from Sewage to Outfall = 89·7 per cent.

May 12th, 1903. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

SEWAGE.— March, 1903.

Average daily flow - - - - - - Month's Rainfall - - - - - -
Maximum daily flow - - - - - - Rainfall - - - - - - -
Minimum daily flow - - - - - - Rainfall - - - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours, pts. per 100,000	2·61	6·96	4·5
Chlorides as NaCl	—	—	13·2
Suspended Solids	—	—	—

Number of samples analysed for the average = 15.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - - - - nil.
Amount of Sludge removed during the month - - - - - - - - - nil.
Average daily flow through the Tanks - - - - - - - - - - —
Average number of Tanks in use - - - - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·45	2·45	1·7
Chlorides as NaCl	—	—	10·81
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

FILTERS.—

Number of times Filters were filled during month - - - - - - - - 47
Amount of Tank Liquor treated per cube yard per 24 hours - - - - - - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·3	1·85	·62
Chlorides as NaCl	—	—	10·85
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

LAND.—

Average Analysis of Final Effluent.

	Best.		Worst.	Average.
Total Solids	68·4		—	—
Loss on Ignition	17·6		—	—
Ash	50·8		—	—
Ammoniacal Nitrogen (single sample)	·97		—	—
Albuminoid Nitrogen	·075	·18	—	—
Nitric Nitrogen	—		—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·49		1·1	·6
Chlorides as NaCl	19·77		—	16·8
Suspended Solids	Trace.		—	—

Number of samples analysed for the average = 47.
Purification from Sewage to Outfall = 86·6 per cent.

May 12th, 1903. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

SEWAGE.— April, 1903.

Average daily flow - - —— - Rainfall - - - - - - ——
Maximum daily flow - - —— - Rainfall - - - - - - ——
Minimum daily flow - - —— - Rainfall - - - - - - ——

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours, parts per 100,000	2·84	8·52	5·96
Chloride as NaCl	—	—	17·15
Suspended Solids	—	—	—

Number of samples analysed for the average = 16.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - - - —
Average number of Tanks in use - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·13	5·21	2·78
Chloride as NaCl	—	—	14·1
Suspended Solids	—	-	—

Number of samples analysed for the average = 17.

FILTERS.—

Number of times Filters were filled during month - - - - 78
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·47	2·16	1·04
Chloride as NaCl	—	—	13·39
Suspended Solids	—	—	

Number of samples analysed for the average = 27.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·1	1·63	·76
Chloride as NaCl	—	—	19·45
Suspended Solids	—	—	—

Number of samples analysed for the average = 61.
Purification from Sewage to Outfall = 87·2 per cent.

Jas. H. Kershaw, F.C.S., Manager.

May 12th, 1903.

ROTHERHAM—*continued.*

May, 1903

SEWAGE.—

Average daily flow - - —— - Rainfall - - - - - ——
Maximum daily flow - - —— - Rainfall - - - - - ——
Minimum daily flow - - —— - Rainfall - - - - - ——

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	4·1	5·0	4·5
Chlorides as NaCl	—	—	14·1
Suspended Solids	—	—	—

Number of samples analysed for the average=3.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - —
Average number of Tanks in use - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	
Albuminoid Nitrogen		—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·85	3·2	2·02
Chlorides as NaCl	—	—	15·51
Suspended Solids	—	—	—

Number of samples analysed for the average = 2.

FILTERS.—

Number of times Filters were filled during month - - - - - 40 ——
Amount of Tank Liquor treated per cube yard per 24 hours - - - ——

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·5	1·6	·8
Chlorides as NaCl	—	—	14·8
Suspended Solids	—	—	—

Number of samples analysed for the average=6.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average
Total Solids	66·8	—	—
Loss on Ignition	14·2	—	—
Ash	52·6	—	—
Ammoniacal Nitrogen (single sample)	—	—	—
Albuminoid Nitrogen	— ·15	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·28	1·6	83
Chlorides as NaCl	19·4	—	19·27
Suspended Solids	1·6	—	—

Number of samples analysed for the average = 27.
Purification from Sewage to Outfall = 81·5 per cent.

Jas. H. Kershaw, F.C.S., Manager.

June 10th, 1903.

ROTHERHAM—*continued.*

SEWAGE.— June, 1903.

Average daily flow - - - - Rainfall - - -

Maximum daily flow - - Rainfall - - - - - -

Minimum daily flow - Rainfall - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	3·55	8·23	5·68
Chlorides as NaCl.	—	—	17·57
Suspended Solids	—	—	—

Number of samples analysed for the average = 11.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - -

Amount of Sludge removed during the month - - - - - -

Average daily flow through the Tanks - - - - - - -

Average number of Tanks in use - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·99	4·42	2·74
Chlorides as NaCl.	—	—	14
Suspended Solids	—	—	—

Number of samples analysed for the average = 7.

FILTERS.—

Number of times Filters were filled during month - - - - - 91

Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·7	1·95	1·38
Chlorides as NaCl.	—	—	14·57
Suspended Solids	—	—	—

Number of samples analysed for the average = 14.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·34	1·66	·97
Chlorides as NaCl.	—	—	18·09
Suspended Solids	—	—	—

Number of samples analysed for the average = 54.

Purification from Sewage to Outfall = 82·9 per cent.

July 21st, 1903. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

July, 1903.

SEWAGE.—

Average daily flow - - - Rainfall - - - - - -
Maximum daily flow - - - Rainfall - - - - - -
Minimum daily flow - - - Rainlall - - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	4·03	9·13	6·5
Chlorides as NaCl.	—	—	19·5
Suspended Solids	—	—	—

Number of samples analysed for the average = 3.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - About 206,000 gallons were pumped into a lagoon.
Average daily flow through the Tanks - - - - - - - —
Average number of Tanks in use - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·46	4·08	3·18
Chlorides as NaCl.	—	—	14·1
Suspended Solids	—	—	—

Number of samples analysed for the average = 5.

FILTERS.—

Number of times Filters were filled during month - - - - - 117
Amount of Tank Liquor treated per cube yard per 24 hours - -

Average Analysis of Filter Effluent

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen		—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·78	2·1	1·13
Chlorides as NaCl.	—	—	14·8
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	
Albuminoid Nitrogen	—	—	
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·39	1·39	·89
Chlorides as NaCl.	—	—	19·0
Suspended Solids	—	—	—

Number of samples analysed for the average 46.
Purification from Sewage to Outfall = 86·3 per cent.

August 6th, 1903.

Jas. H. Kershaw, F.C.S., Manager.

ROTHERHAM—*continued.*

SEWAGE.— August, 1903.

Average daily flow - - - - Rainfall - - - - -
Maximum daily flow - - - - Rainfall - - - - - -
Minimum daily flow - - - - Rainfall - - - - - -

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	5·4	7·32	6·44
Chlorides as NaCl.	—	—	19·27
Suspended Solids	—	—	—

Number of samples analysed for the average = 6.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - nil.
Amount of Sludge removed during the month - - - - 137,000 gallons pumped into a lagoon
Average daily flow through the Tanks - - - - - -
Average number of Tanks in use - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·08	3·49	2·68
Chlorides as NaCl.	—	—	17·15
Suspended Solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS.—

Number of times Filters were filled during month - - - - - 83
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·6	2·26	1·53
Chlorides as NaCl.	—	—	16·45
Suspended Solids	—	—	—

Number of samples analysed for the average = 6.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·16	1·57	·81
Chlorides as NaCl.	—	—	24·67
Suspended Solids	—	—	—

Number of samples analysed for the average = 36.
Purification from Sewage to Outfall = 87·4 per cent.

September 4th, 1903. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

September, 1903.

SEWAGE.—

Average daily flow - - - - Rainfall - - - - - -
Maximum daily flow - - - Rainfall - - - - - -
Minimum daily flow - - - Rainfall - - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	4·16	12·68	7·18
Chlorides as NaCl	—	—	18·9
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - ——
Average number of Tanks in use - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·72	3·18	2·48
Chlorides as NaCl	—	—	15·9
Suspended Solids	—	—	—

Number of samples analysed for the average = 16.

FILTERS.—

Number of times Filters were filled during month - - - - - 72
Amount of Tank Liquor treated per cube yard per 24 hours - - - ——

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·52	2·0	1·23
Chlorides as NaCl	—	—	15·6
Suspended Solids	—	—	—

Number of samples analysed for the average = 23.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·24	1·37	·77
Chlorides as NaCl	—	—	24·3
Suspended Solids	—	—	—

Number of samples analysed for the average = 53.
Purification from Sewage to Outfall = 89·2 per cent.

Jas. H. Kershaw, F.C.S., Manager.

October 10th, 1903.

ROTHERHAM—*continued.*

SEWAGE.— October, 1903.

Average daily flow - - - Rainfall - - - - - -
Maximum daily flow - - - Rainfall - - - - - -
Minimum daily flow - - - Rainfall - - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·2	4·28	2·95
Chlorides as NaCl	—	—	14·57
Suspended Solids	—	—	—

Number of samples analysed for the average = 15.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - nil.
Amount of Sludge removed during the month - - - - nil.
Average daily flow through the Tanks - - - - - - - —
Average number of Tanks in use - - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·96	2·78	1·77
Chlorides as NaCl	—	—	12·92
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

FILTERS.—

Number of times Filters were filled during month - - - - - 53
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·28	1·58	85
Chlorides as NaCl	—	—	11·51
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen		—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·16	·92	·46
Chlorides as NaCl	—	—	18·8
Suspended Solids	—	—	—

Number of samples analysed for the average = 29.
Purification from Sewage to Outfall = 84·4 per cent.

November 5th, 1903. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued*

November, 1903.

SEWAGE.—

Average daily flow - - - - - Rainfall - - - - - - ·126 inches
Maximum daily flow - - - - - Rainfall - - - - - - ·4 „
Minimum daily flow - - - - - Rainfall - - - - - - ·01 „

12 wet days. Total rainfall = 1·51 inches.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·67	7·88	4·25
Chlorides as NaCl	—	—	15·98
Suspended Solids	—	—	—

Number of samples analysed for the average = 22.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - -
Average number of Tanks in use - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·33	3·38	2·36
Chlorides as NaCl	—		12·59
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

FILTERS.—

Number of times Filters were filled during month - - - - - 175
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·33	1·82	·96
Chlorides as NaCl	—	—	12·03
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	
Oxygen absorbed from $KMnO_4$ in 4 hours	·12	·96	·5
Chlorides as NaCl	—	—	17·15
Suspended Solids	—	—	—

Number of samples analysed for the average = 39.

Purification from Sewage to Outfall = 88·2 per cent.

Jas. H. Kershaw, F.C.S., Manager.

December 7, 1903.

ROTHERHAM—*continued.*

SEWAGE.— December, 1903.

Average daily flow - - - —— Rainfall - - - - - ·0753 inches
Maximum daily flow - - - - - —— Rainfall - - - - - ·31 „
Minimum daily flow - - - - - —— Rainfall - - - - ·01 „

15 wet days. Total rainfall = 1·13 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	——	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·4	4·5	3·15
Chlorides as NaCl	—	—	14·05
Suspended Solids	—	—	—

Number of samples analysed for the average = 22.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - - - - ——
Amount of Sludge removed during the month - - - - - - - - - ——
Average daily flow through the Tanks - - - - - - - - - - - ——
Average number of Tanks in use - - - - - - - - - - - - ——

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·2	3·19	1·98
Chlorides as NaCl	—	—	13·0
Suspended Solids	—	—	—

Number of samples analysed for the average = 12.

FILTERS.—

Number of times Filters were filled during month - - - - - - - - 189
Amount of Tank Liquor treated per cube yard per 24 hours - - - - - ——

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·42	1·72	·8
Chlorides as NaCl	—	—	13·0
Suspended Solids	—	—	—

Number of samples analysed for the average = 12.

LAND.—

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·11	·95	·48
Chlorides as NaCl	—	—	13·5
Suspended Solids	—	—	—

Number of samples analysed for the average = 41.
Purification from Sewage to Outfall = 84·7 per cent.
During the year 245 loads of refuse and silt were removed from the screens and catchpits at the works.
January 6th, 1904. *Jas. H. Kershaw, F.C.S.*, Manager.

SUMMARY FOR 1903.

1903.	Loads of Screenings and Silt.	Gallons of Sludge Pumped.	Sewage.			Tank Effluent.				Filtrates.					Outfalls.								
			Number of Samples Examined.	Chlorides Expressed as Solid Chloride.	Oxygen Absorbed (four hours' test) at Lab. Temp.	Number of Samples Examined.	Chlorides as NaCl.	Oxygen Absorbed.	Purification on Sewage.	Number of Samples Examined.	NaCl.	Oxygen Absorbed.	Purification on the Tank Effluent.	Purification on the Sewage.	Number of Samples Examined.	NaCl.	Oxygen Absorbed.	Purification on the Filters.	Purification on the Tank Effluent.	Purification on the Sewage.	Number of Wet Days.	Total Rainfall in Inches.	Number of Filter Fittings.
January	25	—	22	14·8	4·8	20	11·53	1·87	61·0%	19	11·53	·51	—	—	35	28·1	·44	—	—	89·7%	—	—	50
February	8	59,150	10	—	6·43	13	7·82	2·47	—	10	8·65	·69	—	—	36	14·0	·66	—	—	86·6%	—	—	65
March	24	—	15	13·2	4·5	18	10·81	1·7	62·9%	18	10·85	·62	63·5%	86·2%	47	16·8	·6	3·2%	64·7%	87·2%	—	—	47
April	19	—	16	17·15	5·96	17	14·1	2·78	—	27	13·39	1·04	—	—	61	19·45	·76	—	—	81·5%	—	—	78
May	19	—	3	14·1	4·5	2	15·51	2·02	—	6	14·8	·8	—	—	27	19·27	·83	—	—	82·9%	—	—	40
June	22	—	11	17·57	5·68	7	14·0	2·74	—	14	14·57	1·38	49·6%	—	54	18·09	·97	—	—	86·3%	—	—	91
July	24	206,000	3	19·5	6·5	5	14·1	3·18	—	10	14·8	1·13	—	—	46	19·0	·89	—	—	—	—	—	117
August	23	137,000	6	19·27	6·44	4	17·15	2·68	—	6	16·45	1·53	—	—	36	24·67	·81	—	—	—	—	—	83
September	18	—	17	18·9	7·18	16	15·9	2·48	—	23	15·6	1·23	—	—	53	24·9	·77	—	—	—	—	—	72
October	34	—	15	14·57	2·95	10	12·92	1·77	—	10	11·51	·85	—	—	29	18·8	·46	—	—	—	—	—	53
November	13	—	22	15·98	4·25	18	12·59	2·36	—	20	12·03	·96	—	—	39	17·15	·5	—	—	—	12	1·51	175
December	16	—	22	14·05	3·15	12	13·0	1·98	—	12	13·0	·8	—	—	41	13·5	·48	—	—	—	15	1·13	189
Totals	245	402,150	162	—	—	142	—	—	—	175	—	—	—	—	504	—	—	—	—	—	—	—	1,060
Average of monthly results	—	—	—	16·28	5·2	—	13·29	2·34	55·0%	—	13·09	·96	59·0%	81·5%	—	19·48	·68	29·1%	70·9%	87·°/₀	Average=2·9 filters per day.		

James H. Kershaw, F.C.S.,
Chemist and Manager.

ROTHERHAM—*continued.*

January, 1904.

SEWAGE.—

Average daily flow - - - - - Rainfall - - - - - ·133 inches
Maximum daily flow - - - - Rainfall - - - - - ·42 „
Minimum daily flow - - - Rainfall - - - - - ·02 „

16 wet days. Total rain = 2·13 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·82	7·47	5·02
Chlorides as NaCl	—	—	14·8
Suspended Solids	—	—	—

Number of samples analysed for the average = 11.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - nil.
Amount of Sludge removed during the month - 200,000 gallons. This set of tanks had worked 6 months since last sludging.
Average daily flow through the Tanks - - - - an average sample of this sludge contained
85·0 wate.
7·4 organic and volatile matter
7·6 mineral matter (pale brown colour).
100·0
Average number of Tanks in use - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·06	3·12	1·95
Chlorides as NaCl	—	—	11·65
Suspended Solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS.—

Number of times Filters were filled during month - - - - - 134
Amount of Tank Liquor treated per cube yard per 24 hours -

Average Analysis of Filter Effluent.

——	Best	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·63	1·29	·82
Chlorides as NaCl	—	—	12·69
Suspended Solids	—	—	—

Number of samples analysed for the average = 7.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·18	·9	·54
Chlorides as NaCl	—	—	15·55
Suspended Solids	—	—	—

Number of samples analysed for the average = 32.
Purification from Sewage to Outfall = 89·2 per cent..

February 5th, 1904. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

February, 1904.

SEWAGE.—

Average daily flow		Rainfall	·197 inches.
Maximum daily flow		Rainfall	1·62 "
Minimum daily flow		Rainfall	·02 "

19 wet days. Total rain, 3·75 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·07	3·76	2·95
Chlorides as NaCl	—	—	12·45
Suspended Solids	—	—	—

Number of samples analysed for the average = 8.

TANK LIQUOR.—

Amount of Chemicals used during the month	nil.
Amount of Sludge removed during the month	nil.
Average daily flow through the Tanks	—
Average number of Tanks in use	6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen		—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·95	1·46	1·2
Chlorides as NaCl	—	—	10·34
Suspended Solids	—	—	—

Number of samples analysed for the average = 6.

FILTERS.—

Number of times Filters were filled during the month	81
Amount of Tank Liquor treated per cube yard per 24 hours	

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·39	·66	·55
Chlorides as NaCl	—	—	13·16
Suspended Solids	—	—	—

Number of samples analysed for the average = 3.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·11	·93	·42
Chlorides as NaCl	—	—	13·93
Suspended Solids	—	—	—

Number of samples analysed for the average = 13.
Purification from Sewage to Outfall = 85·7 per cent.

J. H. Kershaw, F.C.S., Manager.

March 11th, 1904.

ROTHERHAM—*continued.*

March, 1904.

SEWAGE.—

Average daily flow - - - Rainfall - - - - - - ·119 inches.
Maximum daily flow - - - R infall - - - - - - ·4 „
Minimum daily flow - - - Rainfall - - - - - - ·01 „

15 wet days. Total rain = 1·78 inches.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·9	4·63	3·59
Chlorides as NaCl	—	—	13·6
Suspended Solids	—	—	—

Number of samples analysed for the average = 14.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - nil.
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - - —
Average number of Tanks in use - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·1	4·01	2·44
Chlorides as NaCl	—	—	12·86
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

FILTERS.—

Number of times Filters were filled during month - - - - 190
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·36	1·68	·9
Chlorides as NaCl	—	—	11·75
Suspended Solids	—	—	—

Number of samples analysed for the average = 32.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—		—
Albuminoid Nitrogen	—		—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·11	·86	·5
Chlorides as NaCl	—	—	13·86
Suspended Solids	—	—	—

Number of samples analysed for the average = 42.
Purification from Sewage to Outfall = 86 per cent.

April 9th, 1904. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

April, 1904.

SEWAGE.—

Average daily flow - - - Rainfall - - - - - - - ·104 inches
Maximum daily flow - - Rainfall - - - - - - - ·39 ,,
Minimum daily flow - - Rainfall - - - - - - - ·01 ,,

14 wet days. Total rain, 1·46 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	3·61	17·5	6·38
Chlorides as NaCl. - - - - - - - - -	—	—	16·21
Suspended Solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 19.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - nil.
Amount of Sludge removed during the month - - - - - - nil.
Average daily flow through the Tanks - - - - - - - —
Average number of Tanks in use - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	1·37	5·18	3·42
Chlorides as NaCl. - - - - - - - - -	—	—	14·45
Suspended Solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 10.

FILTERS.—

Number of times Filters were filled during month - - - - - 168
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - - -	—	—	—
Nitric Nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	·83	2·56	1·45
Chlorides as NaCl. - - - - - - - - -	—	—	15·74
Suspended Solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 16.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - - -	—	—	—
Nitric Nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	·17	1·4	·67
Chlorides as NaCl. - - - - - - - - -	—	—	17·62
Suspended Solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 47.
Purification from Sewage to Outfall = 89·5 per cent.

May 9th, 1904. *Jas. H. Kershaw, F.C.S.*, Manager.

ROTHERHAM—*continued.*

SEWAGE.— May, 1904.

Average daily flow - - - - - - - - —— Rainfall - - - - ·2 inches
Maximum daily flow - - - - - - - - —— Rainfall - - - - ·82 „
Minimum daily flow - - - - - - - - —— Rainfall - - - - ·02 „

12 wet days. Total rain = 2·41 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	4·54	25·49	7·8
Chlorides as NaCl	—	—	16·61
Suspended Solids	—	—	

Number of samples analysed for the average = 23.

TANK LIQUOR.—

Amount of chemicals used during the month - - - - - - - - - nil.
Amount of sludge removed during the month - - - - - - - - - ——
Average daily flow through the tanks - - - - - - - - - - ——
Average number of tanks in use - - - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2.16	6·6	3·96
Chlorides as NaCl	—	—	14·38
Suspended Solids	—	—	—

Number of samples analysed for the average = 11.

FILTERS.—

Number of times Filters were filled during month - - - - - - - - 155
Amount of Tank Liquor treated per cube yard per 24 hours - - - - - ——

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Oxygen absorbed from $KMnO_4$ in 4 hours	·92	*3·19	1·64
Chlorides as NaCl	—	—	15·39
Suspended Solids	—	—	—

Number of samples analysed for the average = 12.
* Corresponding Tank Effluent absorbed 6·6 parts oxygen. After Filter was full, 2 hours contact was given.
Purification = 51·1.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Oxygen absorbed from $KMnO_4$ in 4 hours	·38	1·82	·91
Chlorides as NaCl	—	—	17·62
Suspended Solids	—	—	—

Number of samples analysed for the average = 66.
Purification from Sewage to Outfall = 88·3 per cent.

I detected the presence of Gas liquor in the Sewage at the Works, but after about a week it ceased coming, and we had no more till December.

June 7th, 1904. *Jas. H. Kershaw*, F.C.S., Manager.

ROTHERHAM—*continued.*

June, 1904.

SEWAGE.—

Average daily flow - - - - - - - - —— Rainfall - - - - - ·068
Maximum daily flow - - - - - - - - —— Rainfall - - - ·21
Minimum daily flow - - - - - - - - —— Rainfall - - - - ·01

5 wet days. Total rain = ·34 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	3·83	9·42	6·67
NaCl	—	—	18·89
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

TANK LIQUOR.—

Amount of Chemicals used during the month—

No chemicals were used during the ordinary working, but I used about 30 cwt. of lime waste from an Ammonia Works to clear the top water in the three tanks we sludged; they had worked nine months.

Amount of Sludge removed during the month - - - - - - - - - 225,000 gallons.
Average daily flow through the tanks - - - - - - - - - - - ——
Average number of tanks in use - - - - - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.		Worst.	Average.
Ammoniacal Nitrogen (single sample)	3·496	—	—	—
Albuminoid Nitrogen „ „	·344	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	1·92	3·59	2·9
NaCl	—	—	—	15·62
Suspended Solids	—	—	—	—

Number of samples analysed for the average = 5.

FILTERS.—

Total number of times the 4 filters were filled during month - - - - - - 133
Amount of tank liquor treated per cube yard per 24 hours - - - - - - - ——

Average Analysis of Filter Effluent.

——	Best.		Worst.	Average.
Ammoniacal Nitrogen (single sample)	1·922	—	—	—
Albuminoid Nitrogen	·213	—	—	—
Nitric Nitrogen	—	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	·48	1·78	1·25
NaCl	—	—	—	15·51
Suspended Solids	—	—	—	—

Number of samples analysed for the average = 13.

LAND.—

Average Analysis of Final Effluent.

——	Best.				Worst.	Average.
Ammoniacal Nitrogen	1·78	1·43	1·9	1·43	—	—
Albuminoid Nitrogen	·16	·13	·09	·09	—	—
Nitric Nitrogen	—	—	—	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—	·37	1·39	·72
Suspended Solids	—	—	—	—	—	18·09

Number of samples analysed for the average = 57.
Purification from Sewage to Outfall = 89·2 per cent.

July 8th, 1904. *James H. Kershaw*, F.C.S., Manager.

ROTHERHAM—*continued.*

July 1904.

SEWAGE.—

Average daily flow - - - - - - —— Rainfall - - - - 0·174 inches.
Maximum daily flow - - - - - - - - —— Rainfall - - - 0·7 „
Minimum daily flow - - - - - - - - —— Rainfall - - - - 0·01 „

9 wet days. Total rainfall = 1·57 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	6·56	12·	8·19
NaCl - - - -	—	—	18·57
Suspended solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 12.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - - - - - Nil.
Amount of sludge removed during the month - - - - - - - - - - Nil.
Average daily flow through the tanks - - - - - - - - - -
Average number of tanks in use - - - - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed irom $KMnO_4$ in 4 hours - - - -	3·04	5·32	3·75
NaCl - - - - -	—	—	15·
Suspended solids - - - - - - - - - -	—	--	—

Number of samples analysed for the average = 7.

FILTERS—

Number of times filters were filled during month. We have 4 filters. Total fillings=151.
Amount of tank liquor treated per cube yard per 24 hours - - - - -

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - - -	—	—	—
Nitric nitrogen - - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	1·2	2·43	1·76
NaCl - - - -	—	—	14·8
Suspendid solid - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 11.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - - -	—	—	—
Nitric Nitrogen - - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	·28	1·87	1·08
NaCl - - - - -	—	—	17·4
Suspended solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 55.
Purification from Sewage to Outfall = 86·8 per cent.

August 15, 1904 *Jas. H. Kershaw*, F.C.S., Manager.

ROTHERHAM—*continued.*

August,

SEWAGE.—

Average daily flow - - - - - —
Maximum daily flow - - - - - —
Minimum daily flow - - - - - —

Rainfall - - - - - ·39 inches
Rainfall - - - - - 1·51 „
Rainfall - - - - - 0·1 „
9 wet days total Rainfall = 3·51 „

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	4·95	21·6	8·37
NaCl	—	—	19·44
Suspended Solids	—	—	—

Number of samples analysed for the average = 9.

TANK LIQUOR.—

Amount of chemicals used during the month - - - - - - - - - none
Amount of sludge removed during the month - - - - - - - - - none
Average daily flow through the tanks - - - - - - - - - —
Average number of tanks in use - - - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·36	4·02	3·46
NaCl	—	—	14·58
Suspended Solids	—	—	—

Number of samples analysed for the average = 5.

FILTERS.—

Number of times filters were filled during month - - - - 4 filters, Total fillings = 165
Amount of Tank Liquor treated per cube yard per 24 hours - - - - - - —

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·61	1·84	1·23
NaCl	—	—	15·06
Suspended solids	—	—	—

Number of samples analysed for the average = 11.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·2	1·24	·66
NaCl	—	—	15·55
Suspended solids	—	—	—

Number of samples analysed for the average = 52.
Purification from Sewage to Outfall = 92·1 per cent.

September 5th, 1904.

J. H. Kershaw, F.C.S., Manager.

ROTHERHAM.—*continued.*

September, 1904.

SEWAGE.—

Average daily flow - - - —— Rainfall - - - - ·152 inches (nearly)
Maximum daily flow - - - - —— Rainfall - - - - ·39 „
Minimum daily flow - - - - —— Rainfall - - - - ·07 „

6 wet days. Total rainfall = ·91 inches.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in four hours	6·26	18·39	8 68
Chloride as NaCl	—	—	20·41
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

TANK LIQUOR.—

Amount of chemicals used during the month - - - - - - - - - - Nil.
Amount of sludge removed during the month - - - - - - - - - - Nil.
Average daily flow through the tanks - - - - - - - - - - -
Average number of tanks in use - - - - - - - - - - 6

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·81	5 1	3 82
NaCl	—	—	15·66
Suspended Solids	—	—	—

Number of samples analysed for the average = 6.

FILTERS.—

Number of times filters were filled during month - - - - - - Total fillings = 183.
Amount of tank liquor treated per cubic yard per 24 hours - - - -

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·05	1·78	1·42
NaCl	—	—	15·94
Suspended Solids	—	—	—

Number of samples analysed for the average = 12.

LAND.—

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·3	1·42	·85
NaCl	—	—	17·13
Suspended Solids	—	—	—

Number of samples analysed for the average = 62.
Purification from Sewage to Outfall = 90·0 per cent.

October 8th, 1904. *Jas. H. Kershaw*, Manager.

ROTHERHAM—*continued.*

October, 1904.

SEWAGE.—

Average daily flow - - - Rainfall 5 wet days - - Total = ·39 inches.
Maximum daily flow - - - Rainfall - - - - - ·16 „
Minimum daily flow - - - Rainfall - - - - - ·02 „

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	5·8	11·5	7·53
NaCl.	—	—	20·41
Suspended Solids	—	—	—

Number of samples analysed for the average = 16.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - about 1 ton lime (lump) used to clear the top water previous to sludging.
Amount of ludge removed during the month - - - 404,500 gallons.
Average daily flow through the Tanks - - - - sp. gravity of sludge was about 1·075.
Average number of Tanks in use - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·85	5·29	4·36
NaCl.	—	—	16·6
Suspended Solids	—	—	—

Number of samples analysed for the average = 6.

FILTERS.—

Number of times Filters were filled during month - - - - 180 = total fillings of the 4 filters.
Amount of Tank Liquor treated per cube yard per 24 hours - - ——

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·92	2·12	1·31
NaCl.	—	—	16·31
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·36	1·48	·79
NaCl.	—	—	17·65
Suspended Solids	—	—	—

Number of samples analysed for the average = 53.
Purification from Sewage to Outfall = 89·5 per cent.

November 4th, 1904

Jas. H. Kershaw, Manager.

ROTHERHAM—*continued.*

SEWAGE.— November, 1904.

Average daily flow	Rainfall		inches
Maximum daily flow	Rainfall	·24	„
Minimum daily flow	Rainfall	·01	„

11 wet days. Total rainfall = ·97 inches.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	6·3	20·6	9·6
NaCl.	—	—	21·3
Suspended Solids	—	—	—

Number of samples analysed for the average = 15.

TANK LIQUOR.—

Amount of Chemicals used during the month	nil.
Amount of Sludge removed during the month	nil.
Average daily flow through the Tanks	
Average number of Tanks in use	6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·63	5·85	4·41
NaCl.	—	—	16·52
Suspended Solids	—	—	—

Number of samples analysed for the average = 10.

FILTERS.—

Number of times the four Filters were filled during the month	179
Amount of Tank Liquor treated per cube yard per 24 hours	

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·86	2·03	1·49
NaCl.	—	—	14·25
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·48	1·26	·86
NaCl.	—	—	17·65
Suspended Solids	—	—	—

Number of samples analysed for the average = 64.
Purification from Sewage to Outfall = 91 per cent.

December 8th, 1904. *Jas. H. Kershaw*, F.C.S., Manager

ROTHERHAM—*continued.*

December, 1904.

SEWAGE.—

Average daily flow - - - Rainfall - - - - - -
Maximum daily flow - - - Rainfall - - - - - -
Minimum daily flow - - - Rainfall - - - - - -

11 wet days. Total rainfall = 1·44 inches.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	5·46	20·8	11·76
Suspended Solids	—	—	—

Number of samples analysed for the average = 24.

TANK LIQUOR.—

Amount of Chemicals used during the month - - - - - - Nil.
Amount of Sludge removed during the month - - - - - - Nil.
Average daily flow through the Tanks - - - - - - - -
Average number of Tanks in use - - - - - - - - 6

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	5·28	12·5	8·12
Suspended Solids	—	—	—

Number of samples analysed for the average = 7.

FILTERS.—

Number of times Filters were filled during month. The four Filters were filled 136 times.
Amount of Tank Liquor treated per cube yard per 24 hours - - -

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·93	7·85	4·03
Suspended Solids	—	—	—

Number of samples analysed for the average = 7.

LAND.—

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·43	3·74	1·5
Suspended Solids	—	—	—

Number of samples analysed for the average = 34.
Purification from Sewage to Outfall = 87·2 per cent.
An admixture of a trade refuse is the cause of these high figures.
During the year 313 loads of refuse and silt were removed from the screens and catchpits at the Works.
Gas liquor again present in the Sewage.

January 18th, 1905.

Jas. H. Kershaw, F.C.S., Chemist and Manager.

SUMMARY FOR 1904.

1904.	Loads of Screenings and Silt.	Gallons of Sludge Pumped.	Sewage.			Tank Effluent.				Filtrates.					Outfalls.						Number of Wet Days.	Total Rainfall in Inches.	Number of Filter Fillings.
			Number of Samples Examined.	Chlorides Expressed as Sodic Chloride.	Oxygen Absorbed (four hours' test) at Lab. Temp.	Number of Samples Examined.	Chlorides as NaCl.	Oxygen Absorbed.	Purification on the Sewage.	Number of Samples Examined.	NaCl.	Oxygen Absorbed.	Purification on the Tank Effluent.	Purification on the Sewage.	Number of Samples Examined.	NaCl.	Oxygen Absorbed.	Purification on the Filter.	Purification on the Tank Effluent.	Purification on the Sewage.			
January	26	200,000	11	14·8	5·02	4	11·65	1·95	—	7	12·69	·82	—	—	32	15·55	·54	—	—	—	16	2·13	134
February	24	—	8	12·45	2·95	6	10·34	1·2	—	3	13·16	·55	—	—	13	13·93	·42	—	—	—	19	3·75	81
March	16	—	14	13·6	3·59	19	12·86	2·44	—	32	11·75	·9	—	—	42	13·86	·5	—	—	—	15	1·78	190
April	23	—	19	16·21	6·38	10	14·45	3·42	—	16	15·74	1·45	—	—	47	17·62	·67	—	—	—	14	1·46	168
May	22	—	23	16·61	7·8	11	14·38	3·96	—	12	15·39	1·64	—	—	66	17·62	·91	—	—	—	12	2·41	155
June	28	225,000	17	18·89	6·67	5	15·62	2·9	—	13	15·51	1·25	—	—	57	18·09	·72	—	—	—	5	·34	133
July	20	—	12	18·57	8·19	7	15·0	3·75	—	11	14·8	1·76	—	—	55	17·4	1·08	—	—	—	9	1·57	151
August	30	—	9	19·44	8·37	5	14·58	3·46	—	11	15·06	1·23	—	—	52	15·55	·66	—	—	—	9	3·51	165
September	34	—	19	20·41	8·68	6	15·66	3·82	—	12	15·94	1·42	—	—	62	17·13	·85	—	—	—	6	·91	183
October	26	404,500	16	20·41	7·53	6	16·6	4·36	—	10	16·31	1·31	—	—	53	17·65	·79	—	—	—	5	·39	180
November	34	—	15	21·30	9·6	10	16·52	4·41	—	19	14·25	1·49	—	—	64	17·65	·86	—	—	—	11	·97	179
December	30	—	24	Not determined.	11·76	7	—	8·12	—	7	—	4·03	—	—	34	—	1·5	—	—	—	11	1·44	136
Totals	313	829,500	187	—	—	96	—	—	—	153	—	—	—	—	577	—	—	—	—	—	132	20·66	1,855
Average of monthly results	—	—	—	17·52	7·21	—	14·33	3·65	49·37%	—	14·6	1·49	59·18%	79·33%	—	16·55	·8	46·3%	78·08%	88·9%	Average = 5·08 filters per day.		

James H. Kershaw, F.C.S.,
Chemist and Manager.

Mr. K. F. CAMPBELL, M.INST.C.E., called in; and Examined.

21563. (*Chairman.*) You are Mr. K. F. Campbell, Member of the Institute of Civil Engineers and Borough Engineer of Huddersfield?—Yes.

21564. You have kindly come here to-day to speak of your experience of the treatment of sewage, with special reference to the Huddersfield Corporation Sewage Works?—Yes.

21565. What, shortly described, is your system of sewage treatment at Huddersfield?—We have two systems. One is the open septic tank followed by percolation filters for filtration, and the other is chemical precipitation followed by filtration on the system known as double contact.

21566. What is the population draining to the Huddersfield works?—100,000.

21567. What is the system of drainage? That is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent?—The system is the combined one.

21568. Is there any infiltration of subsoil water into the sewers?—Yes.

21569. What is the water supply per head, and from what source does it come?—The water supplied by the Corporation is as follows: For domestic purposes, 14 gallons per head, for trade purposes, 9 gallons per head. There is also a fairly large quantity of water used from wells and borings. The water is supplied from the Corporation reservoirs, the drainage area of the reservoirs is chiefly moorland, or high mountain pasture and millstone grit formation.

21570. Is it hard or soft water?—Soft.

21571. What is the drainage area of the part of the town which is sewered?—About 10,000 acres.

21572. What proportion of the population use pail closets or middens, and what proportion use water-closets?—Seventy per cent. use pail or midden and thirty per cent. use water-closets.

21573. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather in winter and in summer?—Yes, the flow has at times been gauged. Records in the dry summer of 1904 show an average of about 7,000,000 gallons. In winter the average dry weather flow is about 9,000,000 gallons per day.

21574. What is the maximum dry weather rate of flow, and at what hour does this occur?—From 7,000,000 to 12,000,000 gallons during working days, usually greatest at mid-day.

21575. What is the minimum dry weather rate of flow, and at what hour does this occur?—From 3,000,000 to 6,000,000 gallons on Sundays and week nights. Usually lowest about midnight.

21576. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—At the rate of 53,000,000 gallons per day for a very short time.

21577. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation?—Storm overflows are fixed on the branch and main intercepting sewers, and come into operation in most cases when the sewers are running over half full. The sewers are constructed to carry $\frac{1}{8}$ inch rainfall in eight hours before the storm water overflows commence to act. A few of the storm overflows are of the kind known as leaping weirs, and these are arranged in accordance with the gradients of the sewers on which they are fixed.

21578. What is the largest number of gallons of sewage which have passed the last storm overflow and come to your works in 24 hours?—The highest recorded flow has been at the rate of 53,000,000 gallons per 24 hours. The quantity registered for the full 24 hours during which the storm lasted being 18,786,000 gallons (measurements were taken every hour and the average taken).

21579. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—Yes, 7,474,896,000 gallons per annum.

21580. Can you give the Commission an approximate statement as to (a) the volume of sewage which comes to your works during the year; and (b) the volume which passes over your overflows?—The quantity of sewage which comes to the works is 9,000,000 gallons per day, equals 3,285,000,000 gallons per year. I estimate the quantity discharged by the storm overflow at about 1,200,000,000 gallons per year.

21581. Does the infiltration of subsoil waters into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—This varies with the weather and the state of the ground. There is besides subsoil water a considerable quantity of clean water from other sources entering the sewers, stream waters, overflows from reservoirs, condensation water, etc. The amount of extra water entering from these sources is on an average about 2,500,000 gallons per 24 hours.

21582. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of these effluents?—Approximately, four million gallons per 24 hours, of which three millions are derived from processes of woollen manufacture, wool scouring, the nature of which is chiefly soapy dye liquors, and one million derived from other trades, such as cotton spinning and washing, brewing, curriers, gas works, and chemical works.

21583. Has your authority framed any rules as to the reception of trade effluents into sewers? If so, what are they?—Rules have been framed, but up to the present the Corporation have been unsuccessful in putting these in force. They are as follows:—

(1) Volume.—The volume of waste waters shall be reduced as far as practicable, as for example, by keeping condensing water and surface water out of the drains.

(2) All trade waste waters except suds shall first be passed through coke filters on the downward and upward principle before the Corporation can receive the effluent into the sewer.

(3) Suds in all cases shall be treated for the removal of grease, and after sufficient time has been allowed for the precipitation of the grease, the liquid shall be drawn off by means of a floating arm, and after passing through a coke filter on the downward and upward principle, may be discharged to the sewer.

(4) The time of discharge shall be so regulated by the Corporation that all the trade waste shall not discharge into the sewers at the same time.

(5) A manhole or other opening shall be provided to the satisfaction of the Corporation, on the line of drain between the mill and the Corporation sewer, and the officers of the Corporation shall have the right to take samples at this point, and to inspect the tanks at any reasonable time.

(6) Before commencing any works for the treatment of trade waste waters, plans shall be submitted to the Corporation for their approval.

(7) In the event of any of the foregoing conditions not being complied with, the liberty to discharge trade effluents shall be *ipso facto* suspended so long as such non-compliance continues.

21584. Do you find that the trade effluents interfere with the process of purification?—Yes, they render the purification of the sewage more difficult. The nature of the liquids, the chief part of which are soapy dye liquors, makes their purification difficult, the trade refuse being not so amenable to treatment as domestic sewage. The sewage, too, is very variable in composition and in volume, due to the irregular manner in which the trade refuse is discharged into the sewer. The largely increased volume of the sewage to be dealt

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with, and the solids present in the trade liquids give a large quantity of sludge to be disposed of.

21585. In dry weather, what is the average amount of suspended matter in the sewage, and what are the highest and lowest figures?—In dry weather the average amount of suspended solid matter is about 40·0 parts per 100,000. The maximum being 82·5 and the minimum being 23·5. (These are the figures for a dry month.)

21586. What is the physical character of these solids?—Dark grey, almost black, fine particles that settle fairly well.

21587. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—The average analysis of sewage in summer 1903 was—

(April–September) in parts per 100,000.

Nitrogen from Ammonia free, 0·75—Oxygen absorbed 4 hours at 80° F. = 10·66.
Nitrogen from Ammonia Albuminoid—0·677; Chlorine = 13·6.

The average analysis in winter 1903 (January–March and October–December) was:—

Parts per 100,000.

Nitrogen from Ammonia free, 0·83—Oxygen absorbed 4 hours at 80° F. = 8·9.
Nitrogen from Ammonia Albuminoid 0·453—Chlorine = 10·6.

In Summer 1904 (April–September.)

Parts per 100,000.

Nitrogen from Ammonia free, 1·25—Oxygen absorbed 4 hours at 80° F. = 11·3.
Nitrogen from Ammonia Albuminoid 0·675—Chlorine = 14·4.

In Winter 1904 (Jan.-March and Oct.-Dec.).

Parts per 100,000.

Nitrogen from Ammonia free, 1·17—Oxygen absorbed 4 hours at 80° F. = 10·74.
Nitrogen from Ammonia albuminoid, 0·691—Chlorine = 12·43.

21588. Is it a "strong" sewage, and, if so, what characterises its strength?—It is not excessive in strength, but the character of the trade refuse which forms about 30 per cent. of the total volume of sewage renders its treatment difficult.

21589. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—There are variations in strength almost every hour, due to the irregular rushes of trade liquids. During the night, on Saturday afternoons and Sundays, and during general holidays, it is of an entirely different nature to the usual week-day sewage, being in the first case of a weak domestic nature, and in the second a fairly strong manufacturing sewage. The effluent during the day does not vary much as a mixing process goes on in the tanks. The night and week-end effluents are, of course, weaker than those of week-days.

21590. How do you think "strength" of sewage as affecting purification is best expressed or measured?—(a) By the amount of nitrogenous organic matter. (b) By the amount of oxidisable organic matter as measured by the four hours' oxygen absorption. Chlorine should also be estimated to show that the sewage and the effluent are identical.

21591. Have you any information as to the bacteriological condition of your sewage in dry weather and in storm times?—No reliable information on the point at present. Investigations are in operation.

21592. Are there any chemical poisons in the sewage?—Yes, there are frequently coal tar products, aniline, nitrobenzenes, phenols, etc. The quantities vary, some days the whole works are pervaded by the characteristic odour of nitrobenzene, whilst at other times there is no trace of such an odour.

21593. Is the sewage always alkaline?—It is nearly always alkaline; at times it is acid for short periods, due to the sudden rushing of an acid liquor down the sewers.

21594. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—Yes, and they vary as to the condition of the sewers before the storm as well as the rate of inclination to which the sewers are constructed. It would, I think, be misleading to give figures under this head.

21595. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—The main intercepting sewer was constructed in 1881 to 1885. Branch sewers have been constructed at various times from that date up to the present time. There are no instances where the sewers are sunk so as to allow solids to accumulate.

21596. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—The first flush is very polluting for about an hour, after which it becomes weaker according to the length of the storm. Analyses give the oxygen absorbed of liquid portion, after settlement: (a) Dry weather, 8·94; (b) wet weather, 5·60.

21597. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board, are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—The requirements of the Local Government Board appear to me to work satisfactorily in the majority of cases. There are instances, however, where the conditions laid down by the Board can only be adopted with considerable difficulty on the part of local authorities, for the reason that the treatment by the ordinary plant of three times the normal dry weather flow must expose the plant to a certain amount of damage, and therefore I think the Board's requirements might be modified so as to provide for the treatment of any surplus over the dry weather flow, and up to six times that volume, in sedimentation tanks, and then on storm beds specially provided for that purpose. When the storm sewage is not very polluting, it should be dealt with in the manner suggested rather than by the ordinary plant. After six times the dry weather flow the storm water could go direct into the river.

21598. What shape and size are your storm overflows?—Circular in shape, and from 2ft. 0in. to 3ft. 9in. in diameter.

21599. Would it be possible to have a standard form of overflow?—It would not be possible.

21600. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—The better test would be to fix storm overflows to a certain fixed volume of flow independent of the configuration or character of the ground.

21601. Should storm overflows be fixed or movable?—Fixed.

21602. Do you think the number of dilutions at which storm sewage may properly be allowed to pass

into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight while in others this would not be the case?—This would depend entirely upon the size, nature, and location of the stream. It is quite possible that in some cases no injury to the stream would be caused by admitting storm overflows at slightly increased flows, whilst in others it would be dangerous to public health.

21603. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers?—This depends entirely on the method of treatment. It is impossible to fix a general rule in such cases.

21604. Is the Huddersfield sewage settled, and, if so, how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—Settlement by sedimentation alone has not been tried to any great extent. For a short period the septic tank was used at about twice its ordinary rate (*i.e.*, 10 hours in tank instead of 24 hours), when practically only a settling action went on. The results in this case were practically the same as in the case of septic action.

21605. Have you data to show what proportion of the suspended matter in your sewage is settled in ½-hour, 1, 2, 3, 4, 5, 6, 12, and 24 hours, if the sewage is given quiescent settlement?—I have no reliable data.

21606. What time would be necessary for you to gain a good tank liquor containing, say, no more than 6 or 8 parts of suspended solids per 100,000 from your sewage (without the addition of chemicals) by quiescent settlement and by continuous flow settlement?—Eight hours by continuous flow.

21607. Do you prefer to use settlement tanks in series or in parallel?—In parallel.

21608. In the case of continuous flow tanks, do you think there is any advantage in the employment of baffling boards or walls?—There is a slight advantage in the employment of baffling boards; they prevent the sludge from accumulating at the outlet end of the tank.

21609. How is the sludging of tanks done at your works, and what is the character of the sludge? Does any nuisance attend the operation, and, if so, is it serious? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from your tanks?—The clear liquid is run off by means of floating arms, and the sludge removed by means of sludge conduits to a receiving chamber, raised by compressed air, pressed and burnt—a most costly arrangement. We have used sludge lagoons, in which additional septic action takes place without the least nuisance attending the operation.

21610. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—Certainly, all grit should, in the first instance, be removed by the aid of detritus tanks.

21611. What is the manurial value of your sludge, and will farmers take it?—It has no manurial value, and farmers will not take it in this district.

21612. Are there any chemical poisons in it?—None.

21613. Do you find any nuisance from the treatment of sewage in settlement tanks? Have any complaints been made?—No.

21614. Have you had experience of the chemical precipitation of sewage?—Yes, for 26 years.

21615. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—No; generally I have had as good an effluent from the contact beds, treating chemically precipitated sewage as from those treating septic tank effluent.

21616. Have you tried various chemicals? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—Yes. Ferrozone used and quickly abandoned. Cost about £4 per million gallons, and gave a purification of 31 per cent., as measured by the albuminoid ammonia. Treatment with lime and copperas was successfully adopted for seven years at a cost of about 17s. 11d. per 1,000,000 gallons, and purification 54 per cent. Very satisfactory. The percentages here given are based on the workings under same conditions of sewage.

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21617. What is the most effective way of adding chemicals?—In the case of lime, the most effective way is to apply it as milk of lime, and to discharge it into the sewage from five to ten minutes in advance of the copperas.

21618. What is the average analysis of the liquor from your precipitation tanks, and what length of time does the sewage remain in the tanks?—The average analysis of tank effluent from chemical precipitation and subsidence is as follows:—

	Pts. per 100,000.
Nitrogen from free and saline ammonia	1·21
Nitrogen from albuminoid ammonia	0·328
Chlorine	11·70
Oxygen absorbed in 4 hours at 80° F.	5·74
Solids in suspension	7·04

The period of settlement in the tanks is six hours.

21619. What is the character of the suspended matter in such liquor?—The solids in suspension are usually finely divided matters which are difficult to entangle in the precipitate.

21620. Do you find it necessary to add further chemicals to the sludge before it can be dealt with? If so, for what reasons, and what chemicals do you use and how are they added?—Yes; lime is used to render the liquid sludge more manageable before pressing. It causes a better separation of the solid matter. The lime is slaked and made into a cream with water; this is run into the ram along with the sludge, and the whole forced by compressed air into the presses.

21621. What is the manurial value of the sludge obtained by the chemical precipitation of the sewage at your works, and will farmers take it?—The sludge has not much manurial value, owing to the presence of a fairly large quantity of fatty matter, which forms about 20 per cent. of the dry, solid matter.

21622. Does it contain any chemical poisons?—No.

21623. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—No; there is no nuisance, and no complaints have been made.

21624. As regards septic tanks, how should they be shaped?—Long, rectangular.

21625. Should they be divided into sections?—If space is not available for a good length it is advisable to have tanks divided into sections in order to slacken the flow.

21626. Should they be used in series or in parallel?—In parallel.

21627. Is a scum necessary or desirable?—A scum is not necessary.

21628. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—There is not the slightest advantage in a closed tank. There are many disadvantages, such as danger and cost.

21629. What do you consider the best arrangement for the "feed" and "draw-off"?—Delivery a few feet below the surface of the liquid, so as to minimise the disturbance of any deposit, forms the best arrangement for feed. For the draw-off, a long pipe with a slot on the under side, the effluent to pass over a lip or sill, so as to allow for aeration before discharging on to the filters.

21630. At what rate is sewage, as a matter of custom, passed through your septic tanks?—The tank deals with a volume equal to its own capacity every 24 hours.

21631. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at

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which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous? Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with?—For an average sewage, 24 hours in the tank is the most advantageous. Any rate below 12 hours in the tank is disadvantageous, for the reason that complete septic action cannot be obtained under 12 hours, and by leaving the sewage in the tanks more than 24 hours does not produce any better results. Weak sewage can with advantage be passed through the tanks at a much greater rate.

21632. Is it possible to "over-septicise" a sewage, and, if so, for what reasons, and how is the "over-septicising" brought about?—Yes; the products formed by over-septicising being injurious to the nitrifying organisms in the filters. This is brought about by carrying the septic action too far.

21633. What is the amount of digestion in your septic tanks, and how do you calculate this?—About 38 per cent. of the solids deposited in the tank. This is calculated by measuring the sludge left in the tank after a known volume of sewage has been passed through, estimating the solids in the sewage and in the tank effluent during the period, and so calculating the quantity of solid matter deposited. The quantity deposited less the quantity found being the amount digested.

21634. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?—I think it better to let the sludge accumulate until there is a marked increase in the suspended matter coming away with the tank effluent. Then I think the bulk of the sludge should be removed, but not the whole of it, as some should be left in to set up septic action more readily when the tank is refilled.

21635. How often would you clean out the tanks?—The time will vary with the state of the weather and other conditions, but I should say about every six months.

21636. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—The best way is to run it out by means of a sludge valve at the bottom of the tank, and dispose of it either by pressing and burning or by depositing in lagoons, the latter provided special facilities are offered for such a process. No nuisance can be caused by pressing and burning, nor have I found any to prevail by depositing the sludge in lagoons. In the latter case, much depends on the quantity of sludge to be disposed of and the locality.

21637. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank?—Yes, the suspended solids increase towards the end of the period. This is taken as an indication that the tank needs sludging.

21638. What amounts of suspended solids, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—An eleven months trial gave the following:—(a) At commencement: suspended solids =6·6 parts per 100,000; (b) at end: suspended solids =23·3 parts per 100,000; (c) average during period =13·2 parts per 100,000.

21639. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—It is not advisable to pass the storm water through the septic tanks.

21640. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank, and, if so, can you give us figures (in parts per 100,000) showing what the increase is?—I cannot give figures, but believe the solids will remain in the tank under a certain rate of flow.

21641. May you admit storm sewage to your septic tank, to an extent which raises the ordinary level of the liquid, without serious detriment to the functions of the tank?—It would impair septic action for a time.

21642. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way, as *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—I have no information.

21643. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor? Kindly state what observations you have made on this point, along with what you consider the reasons for advantage or disadvantage of the one or other process?—On the assumption that in each case the suspended matter in the tank liquors are the same, septic tanks prepare the sewage better for the beds than either settlement or chemical precipitation. This is, of course, assuming that the sewage is not acid or strongly antiseptic, in which case there would be no septic action. The usually increased quantity of free ammonia indicates that some of the complex nitrogenous bodies have broken up, and present themselves in a form more favourable to oxidation than before, much of the organic matter is given off as gas, whilst the remainder seems to be more easily acted on by the aerobic bacteria than would be the case if no anaerobic action had taken place.

21644. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—Yes. The complex bodies present in sewage are reduced, there being a very much smaller albuminoid ammonia and a smaller quantity of oxygen absorbed than in settled sewage, whilst the free ammonia is higher.

21645. Have you any data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints?—No.

21645*. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—There has been no nuisance, and no complaints have been made.

21646. Do you think it desirable that the suspended solids in sewage should be removed, as far as practicable, before sewage is filtered? If so, what do you consider a practicable limit to get down to? Kindly give the figures in parts per 100,000?—Yes, it is most desirable that the suspended solids should as far as possible be removed before applying the sewage to the beds. I think 6 to 8 parts per 100,000 of suspended solids is a practicable limit to reach for a tank effluent.

21647. How do you consider that this can best be done?—The effluents from chemical precipitation tanks are most free from suspended solids. If, however, a septic tank could be so arranged that a portion of the sludge near to the outlet could frequently be removed, equally good results might be obtained.

21648. Have you any experience of any mechanical device or any special tanks for freeing liquor of suspended matter before delivering it to filters?—None of any value.

21649. What other, if any, method of dealing with tank liquor before delivering it to filters do you regard as necessary or advisable?—None.

21650. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement? I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis. Kindly include the following methods so far as you have experience of them:—Quiescent settlement without chemicals; quiescent settlement with chemicals; continuous flow settlement without chemicals; continuous flow settlement with chemicals; septic tank treatment?—Of the two methods of settlement named, the continuous flow is the better, as this

requires little or no attention, whilst on the quiescent system the tanks must be run off and filled up from time to time. On the assumption that by each of the methods mentioned the same amount of suspended solids will be present in the tank effluent, it would be a waste of money to use chemicals at all, as precipitation only gets rid of matter in suspension. By chemical methods the process would be much quicker, so that it therefore becomes a question of initial cost, standing charges, and space. Septic tanks are, on the whole, the best arrangement. The initial outlay will, of course, be larger, but considering sludge production and subsequent purification of the tank effluent, together with the attention required, I think the annual cost will be very considerably less than with the other methods named.

21651. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—I think it is advisable to employ building material in the construction of contact beds if it should be considered advisable to use such beds at all.

21652. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—They should not be of a greater depth than 4 ft.

21653. What do you consider is the most convenient size for a contact bed?—About one acre.

21654. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—Good hard clinker that will not disintegrate.

21655. What size should the filtering material be, and should it be graded in the beds?—It should not be too fine, and should be graded in the beds. I should suggest for top 6 in. fine clinker ($\frac{1}{4}$ in. to $\frac{5}{8}$ in.); for middle 2 ft. 6 in. medium clinker ($\frac{1}{4}$ in. to 3 in.); bottom, 6 in. rough clinker (5 in. to 6 in.).

21656. How should the bottom of the bed be constructed?—Of concrete, with a slight fall, and underdrained with perforated pipes.

21657. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—Yes, certainly.

21658. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary beds and for secondary beds?—For primary beds one hour filling, two hours standing full, one hour emptying, and four hours resting. The secondary bed at Huddersfield has generally been through a similar cycle to the primary bed, as one is fed directly from the other.

21659. How should contact beds be filled and emptied—They should be fed by means of distributing troughs so arranged as to give pretty equal applications to each section of the bed. They should be emptied by means of a valve placed at the foot of the bed.

21660. If you have had experience of automatic gear for filling and emptying contact beds, would you kindly give your views of such gear?—In my experience all the automatic gear at present on the market falls short of what is required for successful operations for filling and emptying contact beds.

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21661. What amount of tank liquor per cubic yard of filtering material can in practice be properly treated in a primary contact bed per 24 hours? If the amount varies with the quality of the tank liquor, please say by analytical figures what quality of tank liquor you are assuming, and how differences in the tank liquor affect the amount that can be properly treated?—The amount of sewage which can be treated per cubic yard of filtering material varies naturally with the strength and nature of the sewage and tank effluent. It is possible to treat much more in the early morning or during week ends and general holidays than on ordinary week-days. The amount also depends on the rate of silting up of the beds. The beds treating chemically precipitated sewage having an average of suspended solids of 7·0 parts per 100,000 have after a period of three years 31 per cent. of the original liquid capacity of the tank, whilst the bed treating septic tank effluent, with an average of 13·2 parts per 100,000 of suspended matter, has only 25 per cent of the original water capacity of the tank. From these figures, and reckoning on three fills per 24 hours, 156 gallons per cubic yard of effluent from chemical precipitation tanks and 126 gallons per cubic yard of septic tank effluent can be treated daily. Differences in tank liquor affect the amount that can be treated: (1) By reason of strength, the weaker the tank effluent the quicker the treatment; (2) by reason of suspended solids, those having more suspended matter causing the beds to silt up more rapidly than those with less. These quantities are for beds 3ft. 6in. deep.

21662. What amount of liquor from a primary bed can in practice be properly treated on each cubic yard of filtering material of a secondary bed in 24 hours?—The fine bed has a capacity which is 33 per cent. of the original water capacity of the tank, and for a bed 3ft. 6in. deep, having three fills a day, 166 gallons per cubic yard may be treated. It is, of course, possible to treat the effluent from the primary bed more rapidly on the fine bed than has been done at Huddersfield, in which case perhaps four or five fillings a day may be reckoned on.

21663. Can these quantities be increased by more frequent filling and emptying in times of storm without impairing the efficiency of the beds or the quality of the effluents?—These quantities may be increased in times of storm without impairing the efficiency of the bed. The first flush of storm sewage, which is very polluting, should not be allowed on to the beds, but afterwards, as the sewage becomes more dilute, five or six fillings a day may be given with fairly good results.

21664. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent?—For weak tank liquors, such as are usual in times of heavy storms, week-ends, and nights, one contact is sufficient. Tank liquors having an oxygen absorption of from two to four parts per 100,000 with one contact give effluents with from 0·5 to 1·4 parts per 100,000.

21665. At what rate or rates do primary contact beds and secondary contact beds lose their water-holding capacity?—The beds lose their capacity very rapidly at first, and then remain fairly constant for some time, the coarse bed at between 20 and 30 per cent. of original capacity of tank and the fine bed at about 33 per cent. of original capacity of tank. After the end of three years' working the capacity of the coarse bed gradually dropped from 25 per cent. to 16 per cent. of original tank capacity at the end of the fourth year. On resting the beds the capacity increases slightly, but soon falls off again. The following are the records of capacity of beds treating effluent from open septic tank.

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CAPACITY OF COARSE BED.

—	Capacity in Gallons.	Capacity as per cent. of Empty Tank.	Weeks in Operation.	Number of Fills.
Empty tank	6,739	100	—	—
August 22nd, 1900	3,987	59	Initial water capacity.	
September 24th, 1900	2,956	44	5	—
November 13th, 1900	2,730	41	12	—
January 14th, 1901	2,520	37	21	—
March 11th, 1901	2,150	32	29	—
April 15th, 1901	2,030	30	34	—
June 4th, 1901 (after 4 weeks' rest)	2,560	38	41	—
June 10th, 1901	2,220	33	42	—
June 24th, 1901	2,130	32	44	—
July 8th, 1901	2,000	30	46	—
August 19th, 1901	1,900	28	52	—
September 24th, 1901	1,820	27	57	—
October 21st, 1901	1,800	27	61	—
November 25th, 1901	1,820	27	66	—
December 16th, 1901	1,670	25	69	—
January 13th, 1902	1,770	26	73	—
February 14th, 1902 (after 2 weeks' rest)	1,950	29	77	—
March 11th, 1902	1,620	24	81	—
May 26th (after 4 weeks' rest)	2,270	34	92	—
June 10th, 1902	1,940	29	94	—
June 30th, 1902	2,140	32	97	—
July 21st, 1902	2,000	30	99	—
August 5th, 1902	1,940	29	102	—
October 6th, 1902	1,740	26	111	—
October 27th, 1902	1,750	26	114	—
December 22nd, 1902	1,610	24	122	—
January 8th, 1903 (after 2 weeks' rest)	2,050	30	124	—
January 12th, 1903	1,870	28	125	—
March 4th, 903	1,680	25	132	—
April 20th, 1903	1,620	24	135	2 weeks' rest.
June 16th, 1903	1,580	23	143	—
September 21st, 1903	1,580	23	157	—
November 9th, 1903	1,530	23	164	—
January 19th, 1904	1,430	21	174	—
April 11th, 1904	1,390	21	186	—
May 16th, 1904	1,280	19	191	—
August 29th, 1904	1,060	16	206	Rested 1 week
October 3rd, 1904	1,130	17	211	—
December 29th, 1904	1,026	16	223	Rested 3 weeks

With the exception of a short period at the commencement of the experiment and the eighteen weeks of rest the bed had been filled three times per day during six days per week.

FINE BED.

—	Capacity in Gallons.	Capacity as per cent. of Empty Tank.	Weeks in Operation.	Number of Fills.
Capacity of empty tank	6,739	100	—	—
August 22nd, 1900	3,900	59	Initial water capacity.	
February 28th, 1901	2,500	37	28	—
March 11th, 1901	2,250	33	29	—
July 9th, 1901	2,570	38	46	4 weeks' rest.
September 24th, 1901	2,340	35	57	—
October 21st, 1901	2,330	35	61	—
November 25th, 1901	2,340	35	66	—
January 13th, 1902	2,280	34	73	—
December 22nd	2,160	32	122	6 weeks' rest, 2 in February and 4 weeks in May.
March 4th, 1903	2,200	33	132	2 weeks in January, 1903.

The bed is filled directly from the primary bed, and has been treated in the same manner as regards filling and periods of rest.

A small catch-pit is placed between the two beds to keep back some of the suspended solids in the effluent from first contact.

The tank liquor is that from the open septic tank.

AVERAGE ANALYSIS.

—	Nitrogen from Free Ammonia.	Nitrogen from Abuminoid Ammonia.	Oxygen absorbed in Four Hours at 80° F.	Chlorine.
Open Septic Tank	1·91	0·499	6·16	12·10
1st Contact Effluent	0·73	0·263	3·00	—
2nd Contact Effluent	0·18	0·156	1·53	12·00

Suspended Solids in Tank Effluent = 13·1.

Suspended Solids in 1st Contact Effluent = 6·4 (mostly settled before going on to bed).

21666. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed or to the fineness or coarseness of the material of the bed, or on what does it depend?—It varies directly with the quantity of sewage treated, and also with the suspended solids, but not in any fixed proportion. The fineness or coarseness of a bed will also make a difference, as in coarse beds the solid matter has more chance to get to the bottom of the bed and to be washed away with the effluent. The loss also is partly due to degradation and consolidation of the material of the bed.

21667. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard?—This arrangement can be done, and I have done it, but the cost is prohibitive, and should not be entertained.

21668. How can the capacity of contact beds be best maintained?—By keeping the suspended solids in the tank effluent as low as possible, and by having a layer of fine material on the top of the bed which can from time to time be removed and renewed. Also by selecting material for the beds which will not readily disintegrate, and by frequent resting of the bed. Even then I am not prepared to say that the processes named will be effectual.

21669. What is the average analysis of your single contact bed effluent and your double contact bed effluent?—The average analyses are as follows:—

EFFLUENT FROM SINGLE CONTACT.

(a) After Chemical Precipitation and Subsidence.

	Parts per 100,000.
Nitrogen from free and saline ammonia	0·43
Nitrogen from free albuminoid ammonia	0·14
Oxygen absorbed in four hours at 80° F.	2·06
Solids in suspension	3·43

(b) After Open Septic Tank.

	Parts per 100,000.
Nitrogen from free saline ammonia	0·73
Nitrogen from albuminoid ammonia	0.263
Oxygen absorbed in four hours	3.00
Solids in suspension	6.43

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EFFLUENT FROM DOUBLE CONTACT.

(a) After Chemical Precipitation and Subsidence.

	Parts per 100,000.
Nitrogen from free and saline ammonia	0·09
Nitrogen from albuminoid ammonia	0·083
Nitrogen from nitrates and nitrites	0·86
Chlorine	12·00
Oxygen absorbed in four hours	1·10
Suspended solids	2·11

(b) After Open Septic Tank.

	Parts per 100,000.
Nitrogen from free and saline ammonia	0·18
Nitrogen from albuminoid ammonia	0·156
Nitrogen from nitrates and nitrites	0·49
Chlorine	12·0
Oxygen absorbed in four hours	1·53
Solids in suspension	1·86

21669*. Please state the number of gallons of liquid treated daily per cubic yard of filter material in your first bed, and the number of gallons treated daily per cubic yard of filter material in the two filters?—The average quantity treated per cubic yard for the three years 1902-3-4 has been—

(a) After Chemical Precipitation.
186 gallons on coarse bed.
100 gallons for double contact.

(b) After Open Septic Tank.
105 gallons on coarse bed.
71 gallons for double contact.

21670. Do you find any chemical poisons in your final effluent?—No.

21670*. What is the average amount of suspended matter in the primary bed effluent and the secondary bed effluent? Does most of this suspended matter come out with the first flush or not?—The amount of suspended matter in

(a) Primary bed is on an average
3·4 parts per 100,000 after chemical treatment.
6·4 parts per 100,000 after open septic treatment. And in

(b) Secondary bed is
2·1 parts per 100,000 after chemical treatment.
1·86 parts per 100,000 after open septic treatment.

Most of the suspended solids come out in the first five minutes.

21671 To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed is different from the organic matter of the suspended solids going on to that bed?—The solids coming out are usually non-putrescible.

21671*. Is the first flush of effluent from either set of beds ever putrescible?—From primary beds it is very probable indeed that the whole of the effluent is putrescible, except in case of very weak tank liquors. I have no information as to putrescibility of effluents from different sections of the bed. Sometimes, however, the effluent from the second contact is slightly putrescible, and this may be due to the first flush being putrescible.

21672. Do you find that by increasing the number of fillings in storm times or other times the amount of suspended solids is increased?—I have no information on that point.

21673. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency, and, if so, do you think there are advantages in so working them?—Not unless they are constructed of coarse materials.

21674. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per 24 hours in ordinary times and in storm times?—The cost of the contact beds per acre was £1,700. The area of contact beds required to treat 1,000,000 gallons in ordinary times is 2·20 acres. The area required to treat 1,000,000 gallons in times of storm is one acre. This is on the basis of double contact with beds 3ft. 6in. deep.

21675. Have you made any experiments which throw light on the action of contact beds when full and when resting?—No.

21676. Have you made a study of the conditions of aeration of contact beds, and, if so, with what results?—I have made experiments without satisfactory results.

21677. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—No.

21678. As regards continuous or percolating filters, what do you find are the best filtering materials, and what size should the material be?—A good hard clinker which will expose a good filtering surface, and which will not disintegrate. The bed should be fairly coarse, the material used being rejected by a 1½-inch mesh.

21679. What depth should a percolating bed be to obtain a good effluent?—The experimental bed at Huddersfield is 7 ft. deep and gives usually about 90 per cent. purification.

21680. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?—Yes.

21681. Is the material better disposed in the form of two beds, to be fed in succession with the same liquid, or in one dep bed?—One deep bed of an acre in extent is required for large works.

21682. How should percolating filters be fed?—By some form of distributor which will spray the tank effluent evenly over every unit of area of the bed. This is a matter to which I have given a great amount of attention, and I have patented a spreader which provides for an equal distribution of the sewage all over the bed during all conditions of weather. The distributor covers one acre of filter bed.

21683. Should the feed be intermittent or continuous?—The spreader provides the rest required in its revolving action.

21684. What is the best form of distribution, and what are the conditions which have to be fulfilled by a perfect distributor?—The form depends on the shape and size of the filter. A good distributor should fulfil the following conditions:—

1. Every square yard of the bed should receive exactly the same dose of liquid in the same interval of time.
2. The liquid should be sprayed on to the bed in small jets or as a fine rain.
3. There should be no small holes to get easily clogged up.
4. There should be no complicated mechanism to get out of order.
5. They should work as well in high winds or frosty weather as in calm and warm weather.
6. No automatic arrangement possible except for small areas, and even then distributors now in use are subject more or less to weather conditions.

21685. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—The amount may be increased in times of storm without impairing the action of the bed or quality of the effluent. In fact, the increased quantity will tend to flush the bed out and remove any solid matter that may have accumulated.

21686. Is there any practical advantage in artificially heating the liquid which is being treated upon percolating filters?—No.

21687. Have you had any experience to show whether open sides are an advantage to a percolating filter?—Yes, open sides are essential.

21688. Have you made any study of the conditions of aeration of percolating filters?—No.

21689. What do you consider is the most convenient superficial area for a percolating filter?—One acre.

21690. Do you think it desirable that the bottom of a percolating filter be raised from the ground?—Yes, to allow the effluent to get away rapidly and to ensure good aeration.

21691. Do percolating beds, in your experience, choke?—Properly constructed, they do not choke.

21692. Of what nature are the suspended solids in the filter effluent? How much is organic matter, and are they putrescible apart from the liquid portion of the effluent?—The solids are brown earthy matter, and easily settle. About 55 per cent. is organic matter (that is of dried solids). They are not putrescible.

21693. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a percolating filter is different from the organic matter of the suspended solids going to that filter?—The solids are more of a granular nature and are non-putrescent.

21694. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter, and to what minimum figure do you think such settlement or other final treatment can be carried as a practical measure?—Simple settlement will remove the bulk of the solids in suspension, and minimum figure to which such settlement can be carried as a practical measure would be about 3·0 parts per 100,000.

21695. Do you find that the suspended solids in your filter effluent vary much in amount from time to time, and, if so, can you explain the causes of such variation?—The solids are always partly settled before delivery of the effluent, owing to the construction of the tank in which the filter is placed. Therefore suspended solids are not estimated.

21696. What was the cost of your percolating bed installation per acre, and how much liquid do you treat per acre per 24 hours at ordinary times and in storm times? Please give the depth of the filter and an average analysis of the liquid which you put on and an average analysis of the effluent when working at the ordinary rate and when working at a greater rate in storm times. In each case I should like you to give the figures for suspended solids if you have them?—The cost was £2,500 per acre. In ordinary times the filter treats 1·50 million gallons per acre per 24 hours. In storm times the sewage is passed more quickly through the tank and treated continuously during 24 hours at the rate of 1·88 million gallons per acre per day. The depth of the filter is 7 ft. Average analysis (after settlement of suspended solids) in parts per 100,000:—

—	In Ordinary Weather.	In Storm Times.
Nitrogen from Free and Saline Ammonia	0·23	0·05
Nitrogen from Albuminoid Ammonia	0·090	0·049
Nitrogen from Nitrates and Nitrites	1·03	—
Chlorine	11·90	10·70
Oxygen Absorbed in 4 hours	1·29	1·00

21697. Have you made any experiments which throw light on the action of percolating filters with regard to the oxidation of the ammoniacal and organic matter in solution and the organic matter in suspension?—No.

21698. Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter, or that they are absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one?—No.

21699. Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter?—It works equally well in hot or cold weather.

21700. Have you found any trouble from vegetable growths in percolating filters?—No.

21701. Do you find any nuisance from the treatment of sewage on percolating filters? Have any complaints been made?—No.

21702. Would you kindly compare the cost (initial expenditure and annual cost of upkeep and working) and relative advantages of percolating filters and contact beds. Do you consider that one form is best for some kinds of sewage, and the other form for other kinds of sewage?—With regard to initial cost, contact beds require a much bigger area of land, and they also usually require retaining walls, whereas percolating beds have a bigger depth and a much less superficial area; they require practically no retaining walls, large pieces of clinker answering the purpose quite well, so that the original installation would be much more costly if contact beds were used. On the other hand, the sewage can be applied to a contact bed without any special form of distributor, whilst with percolating beds it is essential that some arrangement should be provided for spreading the sewage or tank effluent uniformly over the bed. With regard to cost of upkeep, percolating beds have again the advantage provided that a good form of distributor is used. Beyond some little time for cleaning and repairing the sprinkler no attention is needed, whereas contact beds have to be filled and emptied at regular intervals, and in large installations this can only satisfactorily be done by hand. In addition, the beds require frequent raking or digging over to be able to maintain anything approaching a working capacity. The relative advantages of percolating beds and of contact beds are—

(1) Percolating beds do not require so large an area as contact beds.

(2) Percolating beds do not require retaining walls, which are costly.

(3) Percolating beds do not lose their capacity.

(4) Percolating beds produce an effluent which is usually richer in dissolved oxygen and in oxidised nitrogen than contact beds, and have therefore a bigger reserve supply of oxygen.

(5) The irreducible matter comes away with the effluent in percolating beds, whilst in contact beds it is retained to the detriment of working capacity of the bed.

(6) Contact beds in my experience are not adapted under any circumstances for large sewage schemes.

21703. Do you find that the chance of nuisance is any greater with one form of filter than with another? Does the risk of nuisance depend on the kind of sewage which is being treated or on the nature of the preliminary treatment to which the sewage has been subjected? The question of nuisance is important, and I should be glad if you would state your views fully on these points?—No, both forms of filter are free from smell. Probably with a purely domestic sewage there might be some nuisance caused by the treatment in open septic tanks, but with the sewage of large manufacturing towns, which is weak in domestic refuse and strong in trade refuse, no nuisance is experienced.

21703*. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor or tank liquors could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds? If so, would you kindly state the results, at the same time telling us in precise terms what was the composition of your tank liquor or tank liquors, and what you are considering to be a satisfactory effluent?—Comparisons of the amount of liquid from the open septic tank that could be satisfactorily treated per cubic yard of filtering material show that—

(a) By trickling bed, 132 gallons per cubic yard can be satisfactorily treated.

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(b) By double contact, 72 gallons per cubic yard may be satisfactorily treated (*i.e.*, taking water capacity of coarse bed as 25 per cent. and of fine bed as 33 per cent. of original capacity of empty tank). The composition of the tank liquor is as follows:—

Open Septic Tank.

	Parts per 100,000
Nitrogen from free and saline ammonia	1·91
Nitrogen from albuminoid ammonia	0·499
Chlorine	12·10
Oxygen absorbed in four hours	6·16

The effluent is satisfactory by reason of its non-putrescibility.

21704. Could you express an opinion as to how the number of gallons would vary with variations in the strength of your tank liquor, and on what figure or figures you would rely for defining the "strength" of your tank liquor?—With weak tank liquors I can treat probably half as much again. I should rely on the albuminoid nitrogen and oxygen absorbed figures for defining the strength of the tank liquor.

21705. Have you had any experience of storm water filters?—This is being made the subject of special inquiry at present, but I am unable to state definitely the results.

21706. Do you consider storm water filters lose any of their efficiency by being used intermittently at long intervals?—Yes, it is best to apply weak night sewage at fixed periods.

21706*. Have you any practical suggestions to make for disposing of sludges?—I would suggest that the different kinds should be disposed of as follows:—

(a) Sewage screenings: Tipping or burning.
(b) Material from detritus tank: Tipping.
(c) Sludge from precipitation tanks: Depositing in lagoons.
(d) Sludge from septic tanks: Depositing in lagoons.
(e) Sludge from settlement tanks: Depositing in lagoons.
(f) If the sludge has any manurial value it can be dried in heated cylinders and the moisture thus reduced to 15 per cent., ground in a mill, and sold as manure.

This is the greatest difficulty to contend with in the matter of sewage purification. The methods I have adopted are as follows:—

(1) Deposition on land in specially-prepared sludge lagoons.
(2) Pressing and tipping sludge cake.
(3) Pressing and burning sludge cake.

The pressing and tipping causes in summer time slight smell, due probably to the action of the lime used for pressing liberating gases such as ammonia. No nuisance has been experienced from the other methods. The cost of pressing and burning is, however, considerable.

21707. What, in your opinion, constitutes a good effluent?—One that will remain sweet in the incubator for a week in the absence of air.

21708. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—I find the type of effluent from a contact bed is inferior to the type of effluent from a percolating bed. Nitrification is more active in the percolating bed, and there is also better aeration. So that the effluent has a better reserve supply of oxygen than one from a contact bed.

21709. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—I rely upon the following:—

(1) Incubator test.
(2) Oxidised nitrogen.
(3) Albuminoid nitrogen.
(4) Oxygen absorbed.

The incubator test, I think, is the best test of the quality of an effluent. If a sample will stand in the absence of air for some days at a temperature of a hot summer's day, then it is quite fit to be turned into any watercourse, even if the volume of the effluent exceeds that of the water. (I am referring here to non-potable streams.) The oxidised nitrogen is a very good test of the efficiency of the working of a bed, and also a measure of a reserve supply of oxygen. The albuminoid nitrogen is a measure of matter which is detrimental to the quality of an effluent. The oxygen absorbed is also a measure of matter which is often detrimental, and will indicate to some extent how the effluent will rob the stream of its available oxygen.

21710. Have you tried the "aeration" test, *i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—A few tests have been made.

21711. Is one standard for all effluents passing into non-potable streams possible and desirable, and, if so, what should it be?—Yes, one standard, but not a chemical one, is possible and also desirable, and it should be one that can be attained equally well by large towns with strong sewages and trade waste as by small villages. The following would appear to meet the case. The effluent should be such that a sample of it will keep without putrescing for some days at a temperature of 80 deg. F. in a tightly stoppered bottle. This is a standard that is easily attained and is equally fair to towns and villages. It does not depend on the absence of more than a certain definite quantity of nitrogenous or oxidisable matter. The ideal of sewage purification should be to produce an effluent that will not putresce; and not the production of an effluent that is poor in a certain class of chemical compounds. A manufacturing effluent often contains matters which according to chemical standards would be classed as unsatisfactory or bad, whereas they are non-putrescent and perfectly harmless. The effluent from the Huddersfield percolating bed has at times had an oxygen absorbed of over 2·0 parts per 100,000, or at others an albuminoid nitrogen of ·12, or even more, and yet remained perfectly sweet in the incubator for seven days at 80 deg. F. The oxygen absorbed is chiefly due to dye liquors, which are oxidisable but are not putrescent, and which are generally present in small quantities in the effluent.

21712. Supposing a general standard to be impracticable, how should a plurality or series of standards be formulated? What amount of suspended matter would you allow in an effluent?—If a general standard be considered impracticable then local standards should be made, in the fixing of which should be taken into account:

1. The character of the stream receiving the effluent.
2. The nature of the sewage and the difficulty of its treatment.

It is not advisable to allow more than five parts per 100,000 of suspended solids. This is a standard which can be easily attained, and an increased quantity would be detrimental to the stream.

21713. What is your experience of the effect of storm water upon filters of various sorts?—I have had experience of the effect of storm water, and from what has been done it is found that generally after the first flush in times of storm the sewage can be treated more rapidly on either contact or percolating beds without any serious detrimental action on the beds.

21714. How far do you consider it advisable for a sewage installation to be worked automatically?—It is inadvisable in the case of large installations for the whole works to be dependent on automatic contrivances as these easily get out of order, and cannot at best be depended on. The sewage treatment should be carefully controlled according to results. This can only be attained by careful watching and the application of frequent tests.

21715. Have you made any systematic observations as to the effects of discharging effluents into streams?—No.

21716. Could you make a short statement setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents, and giving your reasons?—The values of chemical tests vary with local conditions. As a general rule the chlorine figure will give a good guide to the strength of the sewage although this depends largely on local conditions, such as chlorine in water supply, population, system of sewerage, and proportion of domestic or trade sewage. The albuminoid nitrogen and oxygen absorbed give a fairly good indication of the substances which have to be got rid of. The two tests should, I think, be done side by side, and a comparison made. The samples should be analysed when fairly fresh, to make the results of any value, as

the putrefactive changes which go on in a bottle of sewage will break down complex matters and give simpler forms.

Of the tests which are applied to effluents, I attach most value to the incubation test for reasons already stated. Next in importance is oxidised nitrogen, as this tells immediately if the bed is working efficiently. The oxygen absorbed in four hours along with the three minutes test gives a valuable indication of how the oxidation is proceeding, and how the effluent will rob a stream of its oxygen. The albuminoid nitrogen also is a good test of purity of an effluent. The tests should be all made and compared as an effluent cannot be condemned or otherwise on any one test, except the putrescibility as measured by the three minutes oxygen absorption before and after incubation.

21716*. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—The strength of a sewage or tank effluent would, I believe, be best determined by:

Albuminoid nitrogen.
Oxygen absorbed.
Solids in suspension.
Chlorine.

The first three showing strength in matters to be disposed of, and the latter the variations in strength in different weathers. This varies, of course, with local conditions, but should be fairly constant for any one sewage.

21717. Is there any other point upon which you would like to speak at this stage?—If I may express an opinion, I would like to add that the time has now arrived for legislation dealing with the pollution of rivers by one general Act, applicable to the whole country, and the creation of a central governing authority with the necessary scientific officers for administering the Act, holding enquiries and affording equal justice to all concerned, and thus avoiding the difficulties and differences of opinion which inevitably arise between local authorities and the Divisional Boards as now constituted.

21717*. On Question 21580 it struck me that the proportion that goes over the storm overflow in comparison with what goes through your regular works is very large. Do you give the figures with confidence?—I give them from actual facts.

21718. Does it not strike you that a very large quantity goes over your storm overflow?—Yes, a very large quantity goes over, but that is due to the rapidity or the suddenness with which very large volumes come down.

21719. Are the figures you give in Question 21596 under (a) and (b) parts per 100,000?—Yes.

21720. And are they ascertained by the four hours' test?—Yes.

21721. Then on Question 21597 you say that after six times the dry weather flow the storm water can go direct into the river. Have you any particular reason for selecting the figure 6?—My reason for selecting the figure 6 is that after a number of experiments during floods I found that it would not be safe to admit into the river any quantity—taking the average for an extended period—below six times the flow.

21722. (*Colonel Harding.*) You say that your experiments led you to think that less than six times dilution would not be safe. Are we to gather that you think that above six dilutions it is safe to turn into the river?—There may be cases when it would be safe to do so, but as a general rule I find it is not so.

21723. Your objection to dealing with more than six times the flow is that it is unnecessary to deal with it, not that it is impracticable?—Certainly.

21724. (*Chairman.*) On Question 21603 you say it depends entirely on the method of treatment, whether you favour the separate or combined systems of sewerage Can you tell us with what methods of treatment you would favour one and with what the other?—For instance, dealing with the sewage chemically, if you have a combined system, of course, you will have a much larger volume to deal with, and it becomes a very expensive process. If, on the other hand, you are not dealing with the question by chemical precipitation, it would not be such a serious question.

21725. In answer to Question 21632 you say that the products formed by over-septicising are injurious to the nitrifying organisms in the filters. Have you ascertained that by actual experience?—I have.

21726. Then, on Question 21633, can you tell us how you measure the quantity of sludge left in the tank? In what way do you contrive to measure it—it is rather a difficult thing to do?—The way the sludge is measured is this. When the tank effluent is drawn off we ascertain by measurement what is the quantity of sludge left, and in order to verify it from the formulæ dealing with it I have actually weighed a cubic foot of sludge so as to ascertain in fact how it can be measured and how it agrees with other methods applied for arriving at the quantity of sludge produced.

21727. (*Sir William Ramsay.*) Was the cubic foot of sludge dried up as well?—No, it was not dried up; it was just taken up to be pressed.

21728. You ascertained the amount of water in it by experiment?—Yes.

21729. (*Colonel Harding.*) But the sludge at the bottom of the tank would be very much denser than the sludge in the upper part of the accumulation?—Yes.

21730. How do you ascertain the mean between the lower and the upper strata?—There might have been between 2ft. and 3ft. of sludge in the tank; I would at once take a cubic foot or a cubic yard, and take the average of the sludge, so as to get the same intensity all over the cubic foot or cubic yard, as the case might be.

21731. Did you take samples of the top, middle and bottom, and mix them together and take the average?—Yes.

21732. You are quite aware that there would be a very great difference?—Yes.

21733. Probably 95 per cent. of water at the top and 80 per cent. at the bottom?—Yes. I do not know of any method you can employ, except to do it in the way I have mentioned.

21734. The results you have obtained depend entirely on the careful way in which this work was carried out?—Yes. I have had the sludge mixed and the quantities ascertained under my own supervision on several occasions, and the variations were so very slight that I came to the conclusion that the results were perfectly accurate.

21735. (*Sir William Ramsay.*) I suppose that 38 per cent. means that that amount of solids was removed by the septic tank process?—Yes.

21736. (*Chairman.*) May I ask on what observations you found your answer to Question 21641, in which you say that it would impair septic action for a time?—That has been obtained by taking analyses of the sewage in the septic tank during periods of sudden storms. It has been found that with rushes of storm waters coming into the septic tank it did not perform its function so satisfactorily as if it was working under ordinary conditions.

21737. In your answer to Question 21643 you speak from actual experience and observation, I suppose?—I do.

21738. (*Sir William Ramsay.*) Have you a set of analyses published, illustrating the last sentence in your answer to Question 21643?—Yes, they are in the reports which I am putting in. (*See* Appendix: page 185).

21739. (*Chairman.*) In answer to Question 21646 you say that you think that from 6 to 8 parts per 100,000 of suspended solids is a practicable limit to reach for a tank effluent. I suppose you say that after fully considering the matter?—Yes.

21740. Of course, it is a low figure?—Yes.

21741. But you deliberately say that?—I do.

21742. Would that be by cleaning out the tank often or not?—I find that, so far as my experiments go, I can obtain this result if I clean the tank out four times a year.

21743. On Question 21667 it rather surprised me that you should say so positively that the cost of washing would be prohibitive. Can you tell us at all what the cost would be?—In my case, when carrying out the operations here referred to, it came to between £5 and £6 per million gallons.

21744. (*Sir William Ramsay.*) The washing?—Yes.

21745. (*Chairman.*) Can you calculate what the cost was per cubic yard?—I could, and will submit the figures afterwards.

21746. (*Colonel Harding.*) The point we want to get at is whether it is or is not a practicable thing to wash out the material of the contact beds. I think you ex-

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press a strong opinion that it is not practicable financially to do so, and you said something about the cost being so much per million gallons?—Yes.

21747. I do not quite appreciate what that means. What we want to know is what is the cost of washing the material of these beds. That surely must be given at so much per cubic yard?—That can be given, but I could not give it without going into the figures. In my case we deal with the cost per million gallons filtered, not per cubic yard.

21748. What has the flow to do with this particular point?—If you have a double contact, and you purify so much sewage upon a given area of double contact, you will arrive at the cost of the purification per million gallons.

21749. I think I see what you mean now. You mean it is the annual cost reckoned per million gallons?—Certainly.

21750. But in order to reach that have you not to find out what it is per cubic yard?—Yes; I could give that figure, but not off-hand; I have it.

21751. You are unable to give it at present?—I could not give it authoritatively at present. I deal with it per million gallons in all my reports. But it is in my opinion impracticable to carry out the process on a large scale—you cannot do it.

21752. It has been suggested to us by certain witnesses that the cost might be brought down to from 1s. to 2s. per cubic yard. You do not agree with that?—I have heard that for years, but my experience is that it is impossible to bring it down to the figure named and at the same time maintain the total capacity of your beds.

21753. (*Chairman.*) Passing on to Question 21669, comparing the effluent from the double contact, the effluent from the first process was rather better than the effluent from the second. Can you tell us at all how the cost of the two processes compares?—You mean the working cost?

21754. Yes?—In the case of the one there is very little. Take the septic tank, for instance. I reckon it makes a difference of about 30s. per million gallons treated—from 27s. 6d. to 30s.

21755. Then on Question 21670* do you see any reason why the figures should be so curiously inverted? In (a) you say that you get 3·4 parts per 100,000 after chemical treatment, and 6·4 parts per 100,000 after open septic treatment. But in (b) the figures are reversed; there are 2·1 parts per 100,000 after chemical treatment, and only 1·86 parts per 100,000 after open septic treatment?—Yes, it is a curious coincidence. These are the facts as I found them.

21756. They are the facts, but you have no explanation of them?—The explanation is due to the fact that in septic treatment the effluent from the coarse bed is partially settled by passing through a catch-pit before flowing on to the second bed, whereas in chemical treatment as at present arranged such is not the case.

21757. In answer to Question 21687 you say that open sides are essential to a percolating filter. That is a very positive statement; how do you support it?—I have tried both, and found better results from the open.

21758. Then in reply to Question 21691, again about the percolating beds, you say that, properly constructed, they do not choke. From how long experience can you speak?—About 3½ years.

21759. And have you had one percolating bed going the whole of that time?—I have.

21760. And it has not choked?—No.

21761. Or shown any signs of choking?—None whatever.

21762. (*Colonel Harding.*) How close is the material?—It ranges from 6in. to about ¾ of an inch.

21763. From 6in. to about ¾ of an inch?—Yes.

21764. Do you mean the big on the top and the ¾in. in the body?—I have 2in. of ¾in. material on the top.

21765. Where does the 6in. come in?—From the middle downwards.

21766. Graded material?—Yes.

21767. Some of it is as small as ¾in.?—On the surface it is as small as ¾in.

21768. How much?—All over the surface.

21769. But how deep?—About 2in.

21770. A mere surface covering?—Yes.

21771. What is the bulk of the filter composed of?—3in., 4in., and 6in.

21772. Then we may take it that it is a very coarse filter?—It is certainly what you would term a really coarse filter.

21773. (*Chairman.*) Is it in constant working?—Yes, to-day.

21774. And it has been in constant working for 3½ years?—It has.

21775. (*Sir William Ramsay.*) Does not the surface require frequent attention?—No.

21776. Does it not get clogged?—No; I have not touched the surface. I have given strict instructions that it is not to be touched at all unless my attention is called to it, and from the day I put down the filter to the present time it has not been touched. I am bound to say that when I started with the percolating filter I was very much averse to it, but I am now of a different mind. So far as I know from experiments that is the best filter of the present day.

21777. (*Chairman.*) Have you had many analyses made of the filtrates?—Yes, daily.

21778. And you find them good?—Yes.

21779. And you consider that the filter does its work thoroughly?—I do, most certainly. In proof of that I may say that I have advised the Corporation to put down 19 acres of this very same filter in their new scheme, and I would not have done so were I not assured of its success.

21780. (*Colonel Harding.*) We have put to you some important questions in regard to storm waters, and are naturally interested by the answers you have given us. But the opinions that you have expressed are based, I suppose, rather upon what you think should be done than upon what you actually have done at Huddersfield. I may take it, as you have not yet got your works in operation for treating your dry weather flow, that you are certainly not treating four or six dilutions?—No, I am not treating the whole; you are quite right in your observation.

21781. You have said that you think it is undesirable that storm water should be treated through the same plant as the dry weather flow, and that it is better to have a separate plant for storm waters. The impurities in storm water—are they not mainly due to suspended matter?—Yes.

21782. And I think you express the opinion that the settlement of such suspended matter might be improved by special treatment?—Yes.

21783. In any case, if further treatment were required it could be done on a percolating filter?—Yes.

21784. At probably a high rate of flow?—Yes, that is so.

21785. In regard to the sludge which you produced, you say that it has no manurial value and that the farmers will not take it?—Yes.

21786. Are you alluding to septic tank sludge or precipitated?—To both.

21787. You produce a large quantity; what do you do with it?—I burn it, and I put portions on to sludge lagoons. One half is burnt, and the other is put on sludge lagoons, allowed to dry, and then covered over with material, when it gets a hard substance—with earth and other materials.

21788. But before you can burn the sludge you must largely reduce the water in it—probably by pressing?—Yes, I press it.

21789. You press part of the sludge?—I do.

21790. And you burn the cake?—Yes.

21791. Do you do that on a large scale?—Yes.

21792. How much cake do you burn, say, per day?—From 15 to 25 tons a day.

21793. I shall be greatly interested to know whether the burning of the sludge cake causes any nuisance?—None whatever in properly constructed furnaces.

21794. Do you utilise the heat?—Yes.

21795. You do not utilise any of the gases produced by the combustion of the cake?—No.

21796. Has there been any suggestion of making gas from the sludge?—Yes.

21797. But you do not think it practicable?—Certainly not.

21798. Part of your production of sludge you burn, and the remainder, you say, you dry in lagoons and then cover up? But surely that cannot go on for ever. You will reach a time when your available site for such a purpose is all used up, and you will have to burn the whole of it or find some other means of disposing of it?—Yes, in the distant future.

21799. What do you propose to do?—To burn the whole.

21800. In your opinion the burning of cake is a practicable thing?—Certainly.

21801. That is your opinion based upon experiments?—Yes.

21802. You think it is practicable in regard to the cost and also as not causing nuisance?—It does not cause nuisance. Of course, the cost is somewhat heavy, but it is quite practicable to carry out.

21803. Passing on to the septic tanks, your present opinion is that it is well to allow the septic tanks to accumulate sludge up to a certain point and then to empty them. In theory, would it not be desirable to maintain the capacity by the frequent removal of some small portion of the sludge so as not to cause any large accumulation?—I do not think so.

21804. In your answer to Question 21638 you say that your septic tank at the beginning had an effluent which contained only 6·6 parts per 100,000 of suspended matter, whereas later on, when the sludge had accumulated, the 6·6 had risen to 23·3 parts per 100,000 of suspended matter in the effluent?—May I refer again to the question.

21805. In answer to 21638?—Yes.

21806. You say there that as the tank got older and the accumulations rose the amount of suspended matter in the effluent rose also very considerably?—Yes, it does rise.

21807. In other parts of your evidence you have expressed the opinion that it is highly desirable that suspended matter should be as far as possible removed from the effluent going on to the filters; therefore I gather that you must think it a disadvantage that the septic tank should reach this condition which yields so much suspended matter in the effluent?—But in the case of a percolating filter it has not the effect upon it that it would have upon a double contact.

21808. You think that a percolating filter will bear more suspended matter upon it than contact beds?—Certainly; it will wash away through the percolating filter, and it can be intercepted by settlement afterwards.

21809. You do not care very much, therefore, what quantity of suspended matter goes on?—I do, because I consider that even the effluent leaving a percolating filter should be submitted to a certain process of settlement before it goes into the river.

21809*. You appreciate that it would be very important even with percolating filters to keep out suspended matter from the effluent if it is practicable to do so?—Certainly.

21810. Therefore if a septic tank at first passes only 6 parts per 100,000 with its effluent and later on 23, it does appear in the abstract that it is desirable to maintain the capacity so as to prevent that important increase?—Yes, if you attach much importance to the suspended matter. Suspended matter may be quite harmless from a polluting point of view.

21811. Do not you attach much importance to it?—It is of some importance in most cases.

21812. Is it at all practicable—I think you are an engineer—to withdraw daily a small quantity of sludge from a septic tank?—It is quite possible from an engineering point of view to do it, but not advisable.

21813. If it be possible to do it would it not be desirable, so as to maintain the capacity of the septic tank and to get in the effluent from the septic tank a fairly constant quantity of suspended matter?—The only thing is that the septic tank gives slightly better results after it has been in action for a considerable time than it does when it is freshly put into operation.

21814. Obviously, when it has matured, it does better than when it is newly started?—Yes.

21815. But this better result is due to the maturing, and not to the accumulation, surely?—To the maturing, but still the accumulation helps to mature. I am certain it does.

21816. But you do not suggest that the septic tank gives better results because a large quantity of material has accumulated in it?—If you look at the analyses you will find that the best results are obtained after the septic tank has been in operation for a month or for two or three months.

21817-18. What do you mean by the best results?—The best results from the point of view of purification of the effluent as it leaves the septic tank. You get a better effluent after the tank has been in operation for some considerable time than you will get within the first week, fortnight, or month after it has started.

21819. But at the end of the period you say that you got 23 parts per 100,000 of suspended matter in the effluent?—Yes.

21820. You do not suggest that that is a better effluent than one containing six parts, do you?—No, it is not better, and so far as the quantity of suspended matter is measured, the septic action is better; the tank produces a better septic action.

21821. When the tank has matured you get better septic action; when it has only just started you get none. The important point I want to get at is whether it would not be best to maintain a constant quantity of deposit in a septic tank rather than allow it to grow many feet deep?—I quite agree with that.

21822. You agree?—I do, certainly.

21823. You think it quite possible to keep on withdrawing sludge from the septic tank?—Yes. I understood that you wanted the tank always clean.

21824. Always empty?—Yes.

21825. Oh, no?—I agree. That is a different thing altogether.

21826. You say that it is possible with a septic tank to reduce the suspended matter in the effluent under proper conditions to as low as 8 or 9 parts per 100,000?—Yes.

21827. And your way is that near the outlet you shall keep the tank fairly clear from sludge?—Yes.

21828. Would not that work in with what I have been suggesting?—Yes.

21829. Any way, you think that the point is of some importance?—It is indeed.

21830. Have you tried any experiments to obtain that?—Yes.

21831. Could you tell us what they were?—With one of the tanks—a precipitation tank—which I have at the present time the course which you suggest has been followed throughout by drawing off the liquid sludge after it got a certain volume, leaving only a small quantity of sludge at the bottom.

21832. What was the result?—The result, as I have shown here, was a higher degree of purification, with less solids in the tank's effluent.

21833. You express a very strong opinion that contact beds should not be deeper than 4ft. Upon what do you base that opinion. I am referring to your answer to Question 21652, where you say "they should not be of a greater depth than 4ft." What leads you to say that?—In 1898 I started with a series of contact beds 3ft. deep. I increased the height to 3ft. 6in., and I went up to 4ft. and to 4ft. 6in., but I found that at 4ft. 6in. the results were not as satisfactory as they were at 4ft. The experiments went on from time to time over 12 months until I fixed on 4ft. as the maximum height to which a contact bed with our sewage should be constructed. With a depth of 4ft. we get better results than from the 4ft. 6in.

21834. You found a positive deterioration by adding an additional 6 inches?—I did slightly.

21835. Were these experiments carried out with the care necessary to enable you with confidence to make that assertion?—Yes; in fact, they were carried out for a purpose, and the purpose was that in the new scheme which I have designed for Huddersfield I thought contact beds would be the best system to adopt, and I was naturally anxious to get a bed that would give the greatest cubical capacity so as to avoid purchasing additional land.

21836. If you have at present working a 4ft. bed which is giving good results, and if you add 6in. on the top, do you say it is going to make the results

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worse?—Well, put on another foot. Six inches is so very little, but if I put on another foot I get a worse result. That is my experience.

21837. But you have not tried 5ft.?—I have tried up to 4ft. 6in., and found that anything over 4ft. did not improve the efficiency of the bed.

21838. You think that if you have a 4ft. contact bed in good working order and you add a foot to it it will injure the results?—The results are less satisfactory whatever height you go above 4ft.

21839. You speak about the washing of contact beds when they get choked by accumulations being quite prohibitive in cost?—Yes.

21840. Have you really tried on a fairly large scale to wash a contact bed?—I have.

21841. And with proper appliances?—Yes.

21842. And you have no doubt that, situated as you are at Huddersfield, it was quite impracticable?—That is so.

21843. What is the alternative. I take it that a contact bed is bound to sludge up at some time?—Undoubtedly.

21844. Is the only possible alternative to renew the material?—To renew the material, or to turn it over and wash it. I do not know of any other system.

21845. But you said that washing is impracticable?—Yes, from a financial point of view.

21846. Then the only alternative is the renewal of the material?—Yes.

21847. Is that also impracticable financially?—I think it is financially.

21848. Then your opinion is that contact beds themselves are impracticable?—On any large scale I hold very strongly that they are.

21849. You do not think that the contact bed system is one that should be used at all?—I do not think it should be used at all, except perhaps in very small installations, where the cost of renewals would only be trifling.

21850. They are bound to sludge at some time, and it is impracticable financially to renew the material or to wash it?—Yes.

21851. You are in favour of percolating filters?—Certainly.

21852. (*Chairman.*) Will you kindly give us your figure of the price per cubic yard for washing the material?—I will. I find it is not less than 4s. 6d. per cubic yard for every time the material is washed. To treat 9,000,000 gallons per day I estimate 87,120 cubic yards of beds would be required, and to wash these once every 12 months would cost £19,602, which is approximately £6 per million gallons of sewage treated. Even with the washing of the beds once in every 12 months the original water capacity of the beds cannot be maintained.

21853. (*Colonel Harding.*) Passing on to the question of percolating beds, you agree no doubt that the question of distribution upon percolating beds is a matter of primary importance?—Yes.

21854. And I think in one of your answers—to Question 21682—you refer to some distributor which you yourself have devised, and of which you speak with approval. What are the leading features of it?—The leading feature of that distributor is that it provides for equal distribution of the flow during all conditions of weather.

21855. How does it accomplish it?—Because with other important mechanical advantages in the matter of design it is electrically driven.

21856. You do not depend on the force of the sewage to rotate it, but you have an independent motive power, namely, electricity?—Yes, electricity.

21857. You have no holes through which the sewage passes. Then what is the arrangement of distribution?—Of course, the arms are perforated for the sewage to pass through.

21858. There are holes in the arms?—Certainly.

21859. I thought I gathered that you object to holes as being likely to get stopped up?—Oh, no; my statement in that case only refers to the working parts, not to the arms.

21860. Do you find that they do get stopped up?—No. They get slightly stopped up, but it is not very material.

21861. You have not frequently to clean them?—No.

21862. The special feature of your distributor is that it is driven by an independent motor power?—That is one of its advantages; the others may be better explained by plans and specifications which I shall be glad to submit.

21863. (*Sir William Ramsay.*) In your answer to Question 21684 you say that there should be no small holes. What is the size of the holes in your distributor?—If you take the ordinary distributor there is a number of very small holes, and these get clogged up.

21864. (*Colonel Harding.*) But you say in your answer to Question 21684 that there should be no small holes. You do not object to larger holes?—To larger holes I do not.

21865. (*Sir William Ramsay.*) Might we ask what is the diameter of the holes in your distributor?—They graduate from ¼in. to 1in.

21866. (*Colonel Harding.*) The holes to which you object—in your answer you say there should be no small holes—of what size are they? Are holes 1-16in. to be considered as not small holes?—They are small holes.

21867. Is 1-16in. a small hole?—Yes.

21868. Then you object to that?—Yes.

21869. What size of hole do you find to be practicable?—Between 1in. and ¼in., according to the size and design of the distributor.

21870. But even with ¼-in. holes do you not have some trouble?—No.

21871. I should like again to refer to a point raised by the Chairman on your answer to Question 21687, about the value of open sides to percolating filters. You express a very strong opinion, I think, as to the value of side aeration. I think you said it was based on experiments which you had carried out. Would you mind telling us the nature of the experiment which led you to this conclusion?—The first experiment that I conducted was with a percolating filter enclosed by a brick wall.

21872. What was the size of the filter?—About 40 ft. square.

21873. What depth?—Between 6 ft. and 7 ft.

21874. The walls were quite solid?—Yes.

21875. What was the alternative filter which you compared with it?—Selected clinker.

21876. What was the size of the alternative filter?—40 ft. diameter.

21877. Circular?—Circular.

21878. The other was of the same dimensions all round?—One was a precipitation tank, and the material was put into this; the other was a circular filter with open sides, the filter material formed the sides in larger blocks built up 7 ft. in height.

21879. Was the size of the material in both the same?—Certainly.

21880. Was the liquor put upon both the same?—The same liquor.

21881. You put identical liquor upon practically identical material, the only difference in the construction being that one was circular and the other square, and you found that better results were obtained from the one with open sides than the one with closed sides?—Yes.

21882. To what extent?—It was very slight.

21883. Do you remember sufficiently to be able to say whether it was 10 per cent. better or not?—It was slightly less than that.

21884. Not so much as 10 per cent.?—Oh, no.

21885. We may take it that, though an interesting point, it is not of very great value in your opinion?—I would not say that, but I am bound to say that if I were advising for any scheme I should have open-side filters.

21886. (*Sir William Ramsay.*) What about expense?—Of course, open sides are cheaper, but I am not altogether on the question of cheapness; it is a question of the best results.

21887. (*Colonel Harding.*) I am not in the least questioning the accuracy of the results which you have obtained. What I want to know is upon what your opinion is based—whether the experiments were carried out under identical conditions and whether the distribution in both cases was the same?—You could not get a comparison unless you did that.

21888. They were exactly the same?—Yes.

21889. Was the aeration at the bottom in both cases the same?—Yes, the same.

21890. These were substantially identical parallel filters?—Parallel filters.

21891. Dealing with the same effluent?—The same tank effluent, the same sewage.

21892. And the final result was that you got an improvement which was less than 10 per cent. in the aerated case?—Yes, and as a result I believe that the open side is preferable to the closed.

21893. To that extent?—Yes.

21894. If it was not 10 per cent. do you think it would be 5 per cent.?—You may take it to be from 5 to 10 per cent.

21895. It was more than 5 per cent.—It would average fully 5 per cent.

21896. You are not able to say, therefore, that side aeration, judged from your experiment, was of very great value?—Dealing with experiments is a different question. When you come to a large area—say of putting down a filter an acre in extent—my argument would probably fall through with the larger area, because if you had open sides for an area of an acre the argument in favour of the open sides would disappear; but I am dealing with the smaller area. If you get by the slightest degree a better result from the open sides, on the larger scale.

21897. I shall not be far wrong if I take your answer to mean this—that you think side aeration of some value, though not of great value, and that if filters are carried out on a large scale the value of side aeration becomes less and less as the filters increase in area?—I should still put them in, but the value undoubtedly becomes less. But I should still employ them for the reason that in a question so difficult as that of sewage purification you cannot afford to disregard one single point of apparent advantage.

21898. There is only one other point. You expressed the view that a percolating filter worked equally well in cold weather and in warm, in winter and in summer?—Yes.

21899. Upon what do you base that opinion?—Upon my own results. My percolating filter has been going summer and winter for 3½ years, and the difference in weather is immaterial.

21900. Have you comparative analyses of the percolating filter in times of severe frost and in summer?—Yes, I have them here; I will put them in.

21901. We shall find when we look at those tables that in severe frost you get quite as much purification from a percolating filter as in warm summer weather?—I have continuous records of seven years of the whole, and I have the continuous records of 3½ years of the percolating filter, and the only difference I find that weather conditions make is that which is due to the fact that the sewage is generally weaker in winter than in summer, owing to a large quantity of rain and snow falling during winter.

21902. What is the loss of temperature in passing through your percolating filters?—I cannot give the exact figures offhand.

21903. Would you not be prepared in the abstract to expect that with sewage reduced in temperature to something approaching freezing point there would be less bacteriological action than in sewage with a temperature of 70 degrees?—I would, and I have been surprised to find in my own case that it was not so.

21904. The opinion you have expressed to us is based upon very careful observation and upon analyses which you have placed before us?—Undoubtedly. Other engineers may say that it does make a slight difference. I find, however, that the difference was so immaterial that it could be disregarded altogether. It is no use putting down a scheme if the filters will not work satisfactorily during the year.

21905. (*Mr. Stafford.*) Why do you think that storm overflows ought to be fixed?—They are more reliable. If you have them automatic they get out of adjustment, and will not work.

21906. You prefer them fixed?—Yes.

21907. In answer to Question 21607 you say that you prefer to use settlement tanks in parallel rather than in series. Why is that?—Tanks in parallel provide for a more equal distribution of the sludge than those in series.

21908. In reply to Question 21639 you say it is not advisable to pass the storm water through the septic tanks. Why do you consider it not advisable?—Because storm water invariably comes down with too great a rush into the septic tank, thereby interfering for a time with septic action, and therefore I think the best results are obtained by putting the storm water after a certain flow comes down on the special filters provided for the purpose.

21909. In answer to Question 21663 you say that the first flush of storm sewage, which is very polluting, should not be allowed on to the beds, but afterwards, as the sewage becomes more dilute, five or six fillings a day may be given with fairly good results. Could you use your beds for any length of time with five or six fillings a day?—Yes, for the length of any storm at least.

21910. Contact beds?—These storm beds are coarse filters?—They are.

21911. (*Major-General Carey.*) With reference to Question 21667, how is the average working capacity to be maintained if the material cannot be washed?—I could not say, the hydraulic value must in that event necessarily decrease.

21912. (*Sir William Ramsay.*) What is the acid that is present as mentioned in your answer to Question 21593—is it sulphuric acid?—Yes, chiefly, and some others from the dye-works.

21913. Is it sulphuric acid employed in making plates?—Yes. Wire drawing or galvanising.

21914. I understand that your sewage is rather fatty, is it not?—There is a good deal of fat.

21915. Is that what makes it combustible, so that you can dry it and burn it?—I do not think so. You can burn it; it is only a question of getting a little extra fuel. The fat helps to burn undoubtedly, but if the fat was less I think I should be able to burn the sludge after being pressed all the same.

21916. Will the sludge burn of itself, or do you require to mix fuel with it?—I mix with it a very small quantity of coke breeze, or in the absence of coke breeze I use house refuse—the cinders that are collected by the scavengers' carts from the houses. It will not burn of itself; it wants a little assistance.

21917. Have you ever estimated what it is worth as fuel?—I suppose you could put a price on it as fuel; very little, if any.

21918. Would it not be worth while to ascertain whether you lose very heavily on pressing and drying the sludge, as against the cost of burning it? You are saving fuel by burning the sludge, though probably your gain is much less than your loss by drying and pressing the sludge?—The process of drying, pressing, and burning is a heavy item inclusive.

21919. Not the process of burning; you gain by that; you save fuel. The process of drying and pressing is expensive?—It is expensive even then.

21920. (*Colonel Harding.*) Can you give us any figures as to the cost of pressing and burning?—Yes; it runs to about 5s. per ton of cake produced. That is a fact that I know, because I have tested it times without number over extended periods, and cannot get the cost less. I have erected specially two of the best furnaces in the country for the burning of sludge, and cannot make any reduction in the cost of burning.

21921. That is clearly not prohibitive, because you are proposing to do it?—It is not prohibitive, although the cost is somewhat heavy.

21922. (*Sir William Ramsay.*) The cost of pressing and drying is 5s. per ton. What is the cost of burning—you naturally get something out of that?—The cost of pressing and drying is at the rate of 2s. 6d. per ton, and the cost of burning another 2s. 6d., making a total of 5s. per ton exclusive of the value of steam produced,

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which may be disregarded altogether in such cases; it is quite a nominal figure.

21923. Granted; but what do you make? How much do you save in coal by burning sludge? Is it worth 2s. as coal?—Much less.

21924. What then?—Nothing, for that matter.

21925. (*Colonel Harding.*) Would it not contain 50 per cent. of moisture?—Yes, it would.

21926. (*Sir William Ramsay.*) You said it would not work for distillation. If it had much fat in it would it not pay for distilling?—Some people believe that there is something in that—extracting the fat and oil. That is a question I am going into, because it is worth trying, and experiments are now in progress.

21927. (*Colonel Harding.*) There is, of course, a very large quantity of residual ash?—Yes.

21928. What becomes of it?—It is very useful to me at present, so far as the clinker is concerned, because I have to prepare a large area of percolating beds for which the clinker is specially adapted.

21929. So that you are really producing material for your beds, and that must be taken into consideration?—Certainly.

21930. It may be put to the credit side, and so reduce the cost which you told us?—Yes.

21931. To what extent?—The estimates which I have got in for my larger scheme are at about 5s. per cubic yard for the filter material which I require.

21932. And this forms filter material?—A certain proportion of it—not more than one-third of it. A good deal of it is ash; a good deal of it disintegrates, and you can only select the best clinker, which is honeycombed and substantially hard and durable.

21933. That is a very valuable point. Are you able to tell us about what proportion of useful material you can obtain from a ton of cake?—About one-third of the quantity.

21934. One-third of the ton?—You mean the proportion of it?

21935. Suppose you had a ton of cake, how much material do you think you could obtain?—About one-third of a ton residue; of that quantity nine-tenths is rather fine material unsuitable for beds, and one-tenth adapted for such purposes.

21936. It is a very important point. If the farmers will not take your cake, and you have to dispose of it, and can do so by burning it, and if by so doing you produce what is useful to you—if that is practicable from a financial point of view—it is an important result?—The clinker has another value; there is nothing better for ground mortar, making street foundations, and so forth. Therefore it has other advantages. I am not going to say that clinker is all waste—far from it.

21937. (*Sir William Ramsay.*) In your answer to Question 21653 you say that one acre is the most convenient size for a contact bed. What is the most convenient size for a percolating filter?—One acre.

21938. Would you have the same size?—Yes, for the reason that the sewage can with certainty be economically and properly applied to each filter.

21939. Do you not find great difficulty in distributing over an area of an acre?—No. With a properly constructed distributor such as I have designed for Huddersfield it can be done perfectly satisfactorily. The Local Government Board have had it under supervision, and have approved of it. I should be glad to send it down to the Commission for them to see it.

21940. In answer to Question 21702 you say that beyond some little time for cleaning and repairing the sprinkler no attention is needed. Is it a fair question to ask how often the sprinkler does require to be cleaned and repaired—is it a frequent process?—It is not a frequent process. The sprinkler should operate successfully for several months. In cases where there is a large installation with irregular flow there must of a necessity be more sprinklers employed upon the work than the ordinary flow requires. In such cases the little attention required in cleaning the arms of the sprinkler can if necessity requires be done by the ordinary staff when the sprinkler is at rest.

21941. So that there is no special stoppage?—No.

21942. In using these percolating beds do you find that they require washing through every now and then?—I have never washed mine for 3½ years.

21943. Not by an extra large supply of water?—No, I never pour water through them.

21944. Do you settle the effluent from these percolating beds, or is it merely a proposal that it might be done?—A proposal to be followed in practice.

21945. You do not do it at present?—No, but I think it should be done; in fact, we are making provision for it now in our new scheme for giving the effluent two hours' settlement before discharging into the river.

HUDDERSFIELD.

Appendix to Evidence of Mr. K. F. Campbell.

Tables showing average analyses of sewage, tank liquors, and filter effluent at Huddersfield.

PROCESSES OF TREATMENT:

(*a*) Chemical Precipitation and Double Contact Beds.

(*b*) Septic Tanks and Double Contact Beds.
(January, 1903, to June 17th, 1903)
(and January 14th, 1904, to December, 1904.)

(*c*) Sedimentation Tanks and Double Contact Beds.
(June 18th, 1903, to January 13th, 1904.)

(*d*) Continuous Filtration after Septic Tanks.
(January, 1903, to June 17th, 1903)
(and January 14th, 1904, to December, 1904.)

(*e*) Continuous Filtration after Sedimentation.
(June 18th, 1903, to January 13th, 1904.)

HUDDERSFIELD.

Month ending January 28th, 1903.

SEWAGE—

Average daily flow - - gallons- - - Total rainfall - - - - - 3·83 inches.
Maximum daily flow - - ,, - Rainfall - - - - - - ,,
Minimum daily flow - - ,, - Rainfall - - - - - - ,,

AVERAGE ANALYSIS OF SEWAGE.

———	Best.	Worst.	Average for Weekdays.
Ammoniacal nitrogen as NH_3	·34	1·44	·96
Albuminoid nitrogen as NH_3	·209	·790	·461
Nitric nitrogen	—	—	—
Chlorine	7·1	16·1	12·0
Oxygen absorbed from $KMnO_4$ in 4 hours	4·29	14·0	9·03
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours ($5\frac{1}{2}$ hours) - - - - - 5,476,000 gallons.
Amount of sewage precipitated during the month - - - - - 153,315,000 gallons.
Amount of chemicals used during the month { Lime - - - - - 19 tons 13 cwts.
Copperas - - - - 11 tons 7 cwts.
Amount of sludge dealt with during the month - - - - - 132,768 cubic feet = 3,850 tons.

Average Analysis of Precipitation Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·64	1·31	·90
Albuminoid nitrogen as NH_3	·104	·320	·217
Nitric nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·70	6·44	4·54
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

Septic Tanks—

Average flow through the tanks per 24 hours - - - - - - 55,000 gallons.
Amount of sewage treated in tanks during month - - - - - 1,540,000 ,,
Amount of sludge dealt with from this process during month - - - nil.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·71	1·64	1·28
Albuminoid nitrogen as NH_3	·196	·371	·286
Nitric nitrogen	—	—	—
Chlorine	7·6	14·4	11·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·00	7·20	5·64
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average (three weeks only) = 15.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 71.
Number of times secondary beds were filled during month - - 71.
Estimate of amount of tank liquor treated per cube yard per 24 hours - 88 gallons, 6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·14	·24	·13
Albuminoid nitrogen as NH_3	·024	·080	·046
Nitric nitrogen	—	—	—
Chlorine	7·1	13·9	11·3
Oxygen absorbed from $KMnO_4$ in 4 hours	·46	1·41	·84
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Contact Beds after Septic Treatment—

Number of times primary beds were filled during month - - - - 51.
Number of times secondary beds were filled during month - - - - 51.
Estimate of amount of tank liquor treated per cube yard per 24 hours - 82 gallons, 6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·09	·20	·14
Albuminoid nitrogen as NH_3	·051	·100	·080
Nitric nitrogen	—	—	—
Chlorine	8·0	13·0	11·6
Oxygen absorbed from $KMnO_4$ in 4 hours	·67	1·6	1·17
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average (3 weeks only) = 15.

Continuous Filter—

Number of hours filter worked during the month - - - - - 208
Amount of tank liquor treated per cube yard per 24 hours - - 66 gallons, 6 days per week.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·29	·54	·37
Albuminoid nitrogen as NH_3	·049	·106	·074
Nitric nitrogen	—	—	—
Chlorine	6·6	13·9	10·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·67	1·8	1·34
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

REMARKS.—During the fortnight ending January 7th, the contact beds after septic treatment were not worked.

April 20th, 1903. *K. F. Campbell*, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending February 25th, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	4·28 inches
Maximum daily flow	,,	Rainfall	,,
Minimum daily flow	,,	Rainfall	,,

Average Analysis of Sewage.

———	Best (Sunday.)	Worst.	Average for Weekdays.
Ammoniacal nitrogen as NH_3	·20	1·60	1·10
Albuminoid nitrogen as NH_3	·111	·990	·60
Nitric nitrogen	—	—	—
Chlorine	2·9	15·1	11·9
Oxygen absorbed from $KMnO_4$ in 4 hours	2·26	14·2	10·7
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5½ hours) - 5,343,000 gallons.
Amount of sewage precipitated during the month - 149,610,000 gallons.
Amount of chemicals used during the month { Lime - 20 tons 10 cwts. / Copperas - 12 tons 19 cwts.
Amount of sludge dealt with during the month - 123,840 cubic feet = 3,591 tons.

Average Analysis of Precipitation Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·30	1·51	1·07
Albuminoid nitrogen as NH	·064	·354	·249
Nitric nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in four hours	1·89	6·86	5·49
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Septic Tanks—

Average flow through the tanks per 24 hours (24 hours) - 55,000 gallons.
Amount of sewage treated in tanks during month - 1,540,000 gallons.
Amount of sludge dealt with from this process during month - none.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	—	1·69	1·60
Albuminoid nitrogen as NH_3	—	·45	·359
Nitric nitrogen	—	—	—
Chlorine	4·1	16·6	12·1
Oxygen absorbed from $KMnO_4$ in 4 hours	3·0	8·11	6·53
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 68
Number of times secondary beds were filled during month - - - - 68
Estimate of amount of tank liquor treated per cube yard per 24 hours - - 84 gallons, 6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·14	·16	·16
Albuminoid nitrogen as NH_3	·024	·090	·059
Nitric nitrogen	—	—	—
Chlorine	6·9	16·6	13·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·41	1·44	1·06
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds after Septic Treatment—

Number of times primary beds were filled during month - - - - 69
Number of times secondary beds were filled during month - - - 69
Estimate of amount of tank liquor treated per cube yard per 24 hours - - 73 gallons, 6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	.20	·26	·21
Albuminoid nitrogen as NH_3	·036	·131	·081
Nitric nitrogen	—	—	—
Chlorine	8·4	16·6	12·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·63	1·67	1·24
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Continuous Filter—

Number of hours filter worked during the month - - - - - - 384
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons, 6 days per week.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·46	·71	·51
Albuminoid nitrogen as NH_3	·069	·149	·093
Nitric nitrogen	—	—	—
Chlorine	7·1	16·5	12·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·7	1·97	1·4
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

April 20th, 1903. *K. F. Campbell*, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending March 25th, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	4·30 inches.
Maximum daily flow	,,	Rainfall	,,
Minimum daily flow	,,	Rainfall	,,

Average Analysis of Sewage.

	Best. (Sunday).	Worst.	Average for Week-days.
Ammoniacal nitrogen as NH_3	·69	1·10	·79
Albuminoid nitrogen as NH_3	·20	·54	·397
Nitric nitrogen	—	—	—
Chlorine	4·9	12·6	8·6
Oxygen absorbed from $KMnO_4$ in 4 hours	2·86	10·8	7·73
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5½ hours)	5,590,000 gallons.
Amount of sewage precipitated during the month	156,525,000 ,,
Amount of chemicals used during the month: Lime	17 tons 17 cwts.
Amount of chemicals used during the month: Copperas	11 tons 12 cwts.
Amount of sludge dealt with during the month	145,152 cubic feet = 4,209 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·69	1·24	·74
Albuminoid nitrogen as NH_3	·129	·310	·20
Nitric nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·00	5·81	3·70
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Septic Tanks—

Average flow through the tanks per 24 hours (24 hours)	55,000 gallons.
Amount of sewage treated in tanks during month	1,540,000 ,,
Amount of sludge dealt with from this process during month	none.

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·76	1·31	·93
Albuminoid nitrogen as NH_3	·22	·396	·26
Nitric nitrogen	—	—	—
Chlorine	6·6	12·9	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	3·1	7·09	4·76
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 71
Number of times secondary beds were filled during month - - - - 71
Estimate of amount of tank liquor treated per cube yard per 24 hours - 80 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·00	·16	·06
Albuminoid nitrogen as NH_3	·036	·06	·043
Nitric nitrogen	—	—	—
Chlorine	5·9	13·0	9·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·43	1·07	·66
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds After Septic Treatment—

Number of times primary beds were filled during month - - - 72
Number of times secondary beds were filled during month - - 72
Estimate of amount of tank liquor treated per cube yard per 24 hours - - 73 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·01	·21	·09
Albuminoid nitrogen as NH_3	·036	·100	·061
Nitric nitrogen	—	—	—
Chlorine	7·1	12·9	8·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·6	1·39	·89
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Continuous Filter—

Number of hours filter worked during the month - - - - - 384
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week).

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen as NH_3	·01	·49	·31
Albuminoid nitrogen as NH_3	·04	·121	·083
Nitric nitrogen	—	—	—
Chlorine	7·1	11·6	8·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·57	1·7	1·23
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

April 20th, 1903. *K. F. Campbell*, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending April 22nd, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	2·09 inches.
Maximum daily flow	„	Rainfall	„
Minimum daily flow	„	Rainfall	„

Average Analysis of Sewage.

——	Best. (Sunday.)	Worst.	Average for Week days.
Ammoniacal nitrogen	·73	1·48	1·12
Albuminoid nitrogen	·30	·89	·57
Nitric nitrogen	—	—	—
Chlorine	5·6	16·1	11·0
Oxygen absorbed from $KMnO_4$ in 4 hours	2·20	11·9	9·64
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks.

Average flow through tanks per 24 hours (5·7 hours)	5,312,000 gallons.
Amount of sewage precipitated during the month	148,725,000 „
Amount of chemicals used during the month: Lime	17 tons 3 cwts.
Amount of chemicals used during the month: Copperas	11 tons 3 cwts.
Amount of sludge dealt with during the month	107,136 cubic feet = 3,107 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·89	1·55	1·10
Albuminoid nitrogen	·233	·459	·309
Nitric nitrogen	—	—	—
Chlorine	11·1	16·9	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·61	6·51	4·81
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

Septic Tanks—

Average flow through the tanks per 24 hours (24 hours)	55,000 gallons.
Amount of sewage treated in tanks during month	1,540,000 „
Amount of sludge dealt with from this process during month	none.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·08	1·73	1·37
Albuminoid nitrogen	·269	·443	·356
Nitric nitrogen	—	—	—
Chlorine	8·4	16·9	11·4
Oxygen absorbed from $KMnO_4$ in 4 hours	3·86	7·04	5·76
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 61
Number of times secondary beds were filled during month - - - - 61
Estimate of amount of tank liquor treated per cube yard per 24 hours - - 80 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·07	·16	·09
Albuminoid nitrogen	·090	·110	·091
Nitric nitrogen	—	—	—
Chlorine	10·4	15·9	12·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·93	1·60	1·03
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

Contact Beds after Septic Treatment—

Number of times primary beds were filled during month - - - 63
Number of times secondary beds were filled during month - - - 63
Estimate of amount of tank liquor treated per cube yard per 24 hours - 70 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·09	·18	·14
Albuminoid nitrogen	·090	·119	·100
Nitric nitrogen	—	—	—
Chlorine	9·4	15·9	11·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·81	1·97	1·21
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

Continuous Filter—

Number of hours filter worked during the month - - - - - 295
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week.)

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·26	·78	·54
Albuminoid nitrogen	·103	·184	·12
Nitric nitrogen	—	—	—
Chlorine	9·4	15·4	12·3
Oxygen absorbed from $KMnO_4$ in 4 hours	·97	2·7	1·74
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

HUDDERSFIELD—*continued.*

Month ending May 20th, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	4·00 inches.
Maximum daily flow	,,	Rainfall	,,
Minimum daily flow	,,	Rainfall	,,

Average Analysis of Sewage.

	Best. (Sunday.)	Worst.	Average for Weekdays.
Ammoniacal nitrogen	·24	1·39	·97
Albuminoid nitrogen	·141	·897	·596
Nitric nitrogen	—	—	—
Chlorine	2·9	16·1	10·6
Oxygen absorbed from $KMnO_4$ in 4 hours	1·69	14·04	9·29
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5·5 hours)	5,544,000 gallons.
Amount of sewage precipitated during the month	155,220,000 ,,
Amount of chemicals used during the month — Lime	18 tons 16 cwts.
Amount of chemicals used during the month — Copperas	14 tons 3 cwts.
Amount of sludge dealt with during the month	142,992 cubic feet = 4,147 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·42	1·35	·98
Albuminoid nitrogen	·140	·417	·306
Nitric nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·06	6·56	4·70
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Septic Tanks.

Average flow through the tanks per 24 hours (24 hours)	55,000 gallons.
Amount of sewage treated in tanks during month	1,540,000 ,,
Amount of sludge dealt with from this process during month	none.

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·50	1·71	1·22
Albuminoid nitrogen	·173	·499	·364
Nitric nitrogen	—	—	—
Chlorine	5·4	16·1	10·6
Oxygen absorbed from $KMnO_4$ in 4 hours	2·39	8·86	5·87
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 68
Number of times secondary beds were filled during month - - - - 68
Estimate of amount of tank liquor treated per cube yard per 24 hours - 80 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·00	·25	·13
Albuminoid nitrogen	·040	·123	·080
Nitric nitrogen	—	—	—
Chlorine	7·0	15·4	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·43	1·59	·91
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds after Septic Treatment—

Number of times primary beds were filled during month - - - - 72
Number of times secondary beds were filled during month - - - 72
Estimate of amount of tank liquor treated per cube yard per 24 hours - 70 gallons (6 days per week).

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·04	·23	·13
Albuminoid nitrogen	·06	·124	·098
Nitric nitrogen	—	—	—
Chlorine	6·6	15·1	11·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·51	1·87	1·14
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Continuous Filter—

Number of hours filter worked during the month - - - - - 327
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week).

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·04	·77	·24
Albuminoid nitrogen	·069	·181	·102
Nitric nitrogen	—	—	—
Chlorine	5·4	16·0	11·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·50	2·76	1·27
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

K. F. Campbell, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending June 17th, 1903.

SEWAGE—

Average daily flow -	gallons -	Total rainfall - - - -	1·17 inches.
Maximum daily flow - -	,, -	Rainfall - - - - -	,,
Minimum daily flow - -	,, -	Rainfall - - - - -	,,

Average Analysis of Sewage.

——	Best. (Sunday.)	Worst.	Average for Week-days.
Ammoniacal nitrogen	1·56	1·80	1·62
Albuminoid nitrogen	·381	·905	·830
Nitric nitrogen	—	—	—
Chlorine	6·90	19·4	13·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·61	16·11	11·6
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (6·9 hours) - - - - - 4,414,000 gallons.
Amount of sewage precipitated during the month - - - - - 123,579,000 ,,
Amount of chemicals used during the month { Lime - - - - 19 tons 11 cwts. / Copperas - - - 13 tons 8 cwts.
Amount of sludge dealt with during the month - - - - - - 138,096 cubic feet = 4,005 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·90	1·72	1·67
Albuminoid nitrogen	·331	·459	·413
Nitric nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	3·3	9.16	6·20
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Septic Tanks—

Average flow through the tanks per 24 hours (24 hours) - - - - 55,000 gallons.
Amount of sewage treated in tanks during month - - - - - 1,540,000 ,,
Amount of sludge dealt with from this process during month - - - 4,800 cubic feet = 139 tons.
First time of sludging since May 10th, 1902. Sewage treated, 21,843,000 gallons.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	2·04	1·97	1·90
Albuminoid nitrogen	·354	·492	·474
Nitric nitrogen	—	—	—
Chlorine	7·9	17·9	13·3
Oxygen absorbed from $KMnO_4$ in 4 hours	4·46	10·06	7·69
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 69
Number of times secondary beds were filled during month - - - - 69
Estimate of amount of tank liquor treated per cube yard per 24 hours - 76 gallons (6 days per week).

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·13	·34	·18
Albuminoid nitrogen	·100	·12	·114
Nitric nitrogen	—	—	—
Chlorine	8·1	19·0	13·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·87	1·84	1·23
Dissolved oxgyen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Contact Beds after Septic Treatment—

Number of times primary beds were filled during month - - - - 69
Number of times secondary beds were filled during month - - - 69
Estimate of amount of tank liquor treated per cube yard per 24 hours - 70 gallons (6 days per week).

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·19	·30	·21
Albuminoid nitrogen	·105	·128	·123
Nitric nitrogen	—	—	—
Chlorine	8·4	17·4	13·6
Oxygen absorbed from $KMnO_4$ in 4 hours	·99	1·96	1·39
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

Continuous Filter—

Number of hours filter worked during the month - - - - - 333
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week).

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·35	·43	·22
Albuminoid nitrogen	·098	·146	·103
Nitric nitrogen	—	—	—
Chlorine	8·4	17·9	14·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·87	1·8	1·21
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

HUDDERSFIELD—*continued.*

Month ending July 15th, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	1·24 inches.
Maximum daily flow	,,	Rainfall	,,
Minimum daily flow	,,	Rainfall	,,

Average Analysis of Sewage.

	Best. (Sunday.)	Worst.	Average for Week-days.
Ammoniacal nitrogen	2·28	1·48	1·65
Albuminoid nitrogen	·479	·872	·833
Nitric nitrogen	—	—	—
Chlorine	9·0	18·4	15·57
Oxygen absorbed from $KMnO_4$ in 4 hours	5·96	15·70	13·56
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (7·2 hours)	4,223,000 gallons.
Amount of sewage precipitated during the month	118,233,000 gallons.
Amount of chemicals used during the month: Lime	22 tons 14 cwts.
Amount of chemicals used during the month: Copperas	15 tons 5 cwts.
Amount of sludge dealt with during the month	147,600 cubic feet = 4,280 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·56	1·44	1·76
Albuminoid nitrogen	·397	·557	·466
Nitric nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	6·64	9·26	8·14
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Sedimentation Tank—

Average flow through the tanks per 24 hours (10 hours)	131,000 gallons.
Amount of sewage treated in tanks during month	3,144,000 ,,
Amount of sludge dealt with from this process during month	none.

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·64	1·97	1·74
Albuminoid nitrogen	·390	·495	·445
Nitric nitrogen	—	—	—
Chlorine	12·0	15·86	15·14
Oxygen absorbed from $KMnO_4$ in 4 hours	6·80	9·21	8 26
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 15.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 70
Number of times secondary beds were filled during month - - - - 70
Estimate of amount of tank liquor treated per cube yard per 24 hours - - 76 gallons (6 days per week).

Average Analysis of Filter Effluent.

——	Best.	Worst.	verage.
Ammoniacal nitrogen	·09	·23	·23
Albuminoid nitrogen	·102	·165	·136
Nitric nitrogen	—	—	—
Chlorine	15·6	17·00	16·57
Oxygen absorbed from $KMnO_4$ in 4 hours	1·36	2·27	1·74
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 61.
Number of times secondary beds were filled during month - - - 61
Estimate of amount of tank liquor treated per cube yard per 24 hours - - 1st week, none; 2nd, 3rd, and 4th weeks, 70 gallons (6 days per week).

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·18	·26	·21
Albuminoid nitrogen	·123	·187	·165
Nitric nitrogen	—	—	—
Chlorine	13·57	16·0	15·86
Oxygen absorbed from $KMnO_4$ in 4 hours	1·97	2·67	2·29
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 15.

Continuous Filter.

Number of hours filter worked during the month - - - - - 244.
Amount of tank liquor treated per cube yard per 24 hours - - - - 1st week, none; 2nd week, 66 gallons; 3rd and 4th week, 132 gallons (6 days per week).

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·09	·57	·19
Albuminoid nitrogen	·089	·144	·126
Nitric nitrogen	—	—	—
Chlorine	15·9	19·0	15·9
Oxygen absorbed from $KMnO_4$ in 4 hours	1·37	2·44	1·71
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 14.

August 21st, 1903. *K. F. Campbell*, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending August 12th, 1903.

SEWAGE—

Average daily flow - -	gallons.	Total rainfall - - - -	2·31 inches.
Maximum daily flow - -	,,	Rainfall - - - - -	,,
Minimum daily flow - -	,,	Rainfall - - - - -	,,

Average Analysis of Sewage.

——	Best (Sunday.)	Worst	Average for Week-days.
Ammoniacal nitrogen - - - - - - - -	·98	1·67	1·37
Albuminoid nitrogen - - - - - - - -	·384	·766	·713
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	7·4	17·6	13·1
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	3·66	13·24	11·33
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (7·1 hours) - - - -	4,236,000 gallons.
Amount of sewage precipitated during the month - - - - -	118,617,000 ,,
Amount of chemicals used during the month { Lime - - - -	21 tons 6 cwts.
{ Copperas - - -	15 tons.
Amount of sludge dealt with during the month - - - - -	158,256 cubic feet = 4,589 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	1·55	1·72	1·49
Albuminoid nitrogen - - - - - - - -	·390	·410	·397
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	5·26	8·16	6·67
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 18.

Sedimentation Tank—

Average flow through the tanks per 24 hours (10 hours) - - - -	131,000 gallons.
Amount of sewage treated in tanks during month - - - - -	3,144,000 ,,
Amount of sludge dealt with from this process during month - - -	46·4 tons.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	1·57	1·47	1·43
Albuminoid nitrogen - - - - - - - -	·220	·397	·391
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	10·0	18·0	13·0
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	4·36	8·46	6·6
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 19.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - 68
Number of times secondary beds were filled during month - - - 68
Estimate of amount of tank liquor treated per cube yard per 24 hours 75 gallons (6 days per week).

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·21	·13	·16
Albuminoid nitrogen	·110	·165	·125
Nitric nitrogen	—	—	—
Chlorine	15·6	10·0	13·0
Oxygen absorbed from $KMnO_4$ in 4 hours	1·20	1·77	1·41
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 69
Number of times secondary beds were filled during month - - - - 69
Estimate of amount of tank liquor treated per cube yard per 24 hours - 70 gallons (6 days per week).

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·14	·18	·14
Albuminoid nitrogen	·119	·151	·152
Nitric nitrogen	—	—	—
Chlorine	13·6	16·4	13·4
Oxygen absorbed from $KMnO_4$ in 4 hours	1·46	2·47	2·00
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

Continuous Filter—

Number of hours filter worked during the month - - - - - - 335
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week).

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·07	·32	·13
Albuminoid nitrogen	·119	·160	·121
Nitric nitrogen	—	—	—
Chlorine	12·1	12·1	12·3
Oxygen absorbed from $KMnO_4$ in 4 hours	1·20	2·19	1·43
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 13.

October 27th, 1903. *K. F. Campbell*, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending September 9th, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	6·13 inches.
Maximum daily flow	„	Rainfall	„
Minimum daily flow	„	Rainfall	„

Average Analysis of Sewage.

——	Best. (Sunday.)	Worst.	Average for Week-days.
Ammoniacal nitrogen	1·11	1·26	1·04
Albuminoid nitrogen	·302	·721	·598
Nitric nitrogen	—	—	—
Chlorine	5·9	17·1	11·9
Oxygen absorbed from $KMnO_4$ in 4 hours	2·71	13·3	9·97
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks:

Average flow through tanks per 24 hours (6·3 hours)	4,821,000 gallons.
Amount of sewage precipitated during the month	134,991,000 „
Amount of chemicals used during the month { Lime	20 tons 2 cwts.
Amount of chemicals used during the month { Copperas	13 tons 19 cwts.
Amount of sludge dealt with during the month	156,816 cubic feet = 4,548 tons.

Average Analysis of Precipitation Liquor:

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·75	1·40	1·17
Albuminoid nitrogen	·331	·344	·341
Nitric nitrogen	—	—	—
Chlorine	9·14	14·86	12·14
Oxygen absorbed from $KMnO_4$ in 4 hours	4·23	7·04	5·64
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 9.

Sedimentation Tank—

Average flow through the tanks per 24 hours (10 hours)	131,000 gallons.
Amount of sewage treated in tanks during month	3,144,000 „
Amount of sludge dealt with from this process during month	62 tons.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·28	1 35	1·24
Albuminoid nitrogen	·282	·406	·330
Nitric nitrogen	—	—	—
Chlorine	9·6	16 0	11·9
Oxygen absorbed from $KMnO_4$ in 4 hours	3·66	8·19	5·70
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

FILTERS—

Contact Bed after Chemical Treatment—

Number of times primary beds were filled during month - - - - 35
Number of times secondary beds were filled during month - - - - 35
Estimate of amount of tank liquor treated per cube yard per 24 hours - 75 gallons (6 days per week) (2 weeks only).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·05	·10	·08
Albuminoid nitrogen	·095	·105	·097
Nitric nitrogen	—	—	—
Chlorine	10·4	13·9	12·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·89	1·53	1·13
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 9.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 35
Number of times secondary beds were filled during month - - - - 35
Estimate of amount of tank liquor treated per cube yard per 24 hours - 70 gallons (6 days per week) (2 weeks only).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·09	—	·12
Albuminoid nitrogen	·106	·147	·131
Nitric nitrogen	—	—	—
Chlorine	11·1	13·6	12·1
Oxygen absorbed from $KMnO_4$ in 4 hours	1·44	2·26	1·69
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 8.

Continuous Filter—

Number of hours filter worked during the month - - - - - - 340

Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week).

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·15	·32	·12
Albuminoid nitrogen	·073	·138	·105
Nitric nitrogen	—	—	—
Chlorine	9·4	11·57	11·86
Oxygen absorbed from $KMnO_4$ in 4 hours	·914	1·67	1·28
Dissolved oxygen taken up in 24 hours	—	—	
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

REMARKS.—The contact beds after chemical treatment were allowed to rest from August 12th to 26th.
The contact beds after sedimentation were allowed to rest from August 12th to 26th.

HUDDERSFIELD—*continued*

Month ending October 7th, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	4·90 inches.
Maximum daily flow	,,	Rainfall	,,
Minimum daily flow	,,	Rainfall	,,

Average Analysis of Sewage.

——	Best. (Sunday.)	Worst.	Average for Weekdays.
Ammoniacal nitrogen	·63	1·28	1·12
Albuminoid nitrogen	·217	·640	·573
Nitric nitrogen	—	—	—
Chlorine	4·86	14·0	12·0
Oxygen absorbed from $KMnO_4$ in 4 hours	2·46	12·7	9·69
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks.

Average flow through tanks per 24 hours (6·1 hours)	4,962,000 gallons.
Amount of sewage precipitated during the month	138,945,000 ,,
Amount of chemicals used during the month { Lime	20 tons 6 cwts.
Amount of chemicals used during the month { Copperas	12 tons 4 cwts.
Amount of sludge dealt with during the month	130,320 cubic feet = 3,779 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst	Average.
Ammoniacal nitrogen	·40	1·03	·88
Albuminoid nitrogen	·211	·445	·302
Nitric nitrogen	—	—	—
Chlorine	6·00	14·9	10·0
Oxygen absorbed from $KMnO_4$ in 4 hours	2·96	8·44	5·04
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 13.

Sedimentation Tank—

Average flow through the tanks per 24 hours (10 hours)	131,000 gallons.
Amount of sewage treated in tanks during month	3,144,000 ,,
Amount of sludge dealt with from this process during month	58 tons.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·41	1·19	1·17
Albuminoid nitrogen	·192	·423	·334
Nitric nitrogen	—	—	—
Chlorine	6·1	14·9	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	3·04	8·10	5·86
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 44
Number of times secondary beds were filled during month - - - - 44
Estimate of amount of tank liquor treated per cube yard per 24 hours - 75 gallons, 6 day per week (3 weeks only).

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·00	·07	·06
Albuminoid nitrogen	·591	·131	·077
Nitric nitrogen	—	—	—
Chlorine	7·4	15·0	10·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·53	1·87	·91
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 12.

Contact Beds after Sedimentation.

Number of times primary beds were filled during month - - - - 67
Number of times secondary beds were filled during month - - - - 67
Estimate of amount of tank liquor treated per cube yard per 24 hours - 70 gallons, 6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·00	·13	·10
Albuminoid nitrogen	·064	·161	·128
Nitric nitrogen	—	—	—
Chlorine	7·57	14·9	11·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·91	2·39	1·63
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

Continuous Filter—

Number of hours filter worked during the month - - - - - 332
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons, 6 days per week.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·01	·27	·10
Albuminoid nitrogen	·061	·153	·095
Nitric nitrogen	—	—	—
Chlorine	8·6	15·0	11·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·64	2·43	1·19
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

REMARKS.—The contact beds after chemical treatment were allowed to rest from September 25th to October 4th, whilst the surface layer of the primary bed was being renewed.

HUDDERSFIELD—*continued.*

Month ending November 4th, 1903.

SEWAGE—

Average daily flow	gallons	-	Total rainfall	6·77	inches
Maximum daily flow	„	-	Rainfall	„	
Minimum daily flow	„	-	Rainfall	„	

Average Analysis of Sewage.

———	Best. (Sunday.)	Worst.	Average for Week-days.
Ammoniacal nitrogen	·56	·74	·46
Albuminoid nitrogen	·213	·566	·340
Nitric nitrogen	—	—	—
Chlorine	4·6	12·6	8·7
Oxygen absorbed from $KMnO_4$ in 4 hours	1·71	9·64	6·20
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5·5 hours)		5,482,000 gallons.
Amount of sewage precipitated during the month		153,495,000 „
Amount of chemicals used during the month	Lime	13 tons 1 cwt.
	Copperas	7 tons 3 cwts.
Amount of sludge dealt with during the month		129,168 cubic feet = 3,746 tons.

Average Analysis of Precipitation Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·32	·62	·43
Albuminoid nitrogen	·177	·259	·197
Nitric nitrogen	—	—	—
Chlorine	6·1	10·9	8·5
Oxygen absorbed from $KMnO_4$ in 4 hours	1·94	4·69	3·19
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Sedimentation Tanks—

Average flow through the tanks per 24 hours (10 hours)	131,000 gallons.
Amount of sewage treated in tanks during month	3,144,000 „
Amount of sludge dealt with from this process during month	none.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·49	·70	·50
Albuminoid nitrogen	·157	·220	·181
Nitric nitrogen	—	—	—
Chlorine	6·0	10·4	7·86
Oxygen absorbed from $KMnO_4$ in 4 hours	2·04	4·29	3·07
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 65
Number of times secondary beds were filled during month - - - - 65
Estimate of amount of tank liquor treated per cube yard per 24 hours - 75 gallons, 6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·00	·01	·01
Albuminoid nitrogen	·033	·057	·047
Nitric nitrogen	—	—	—
Chlorine	6·4	10·4	7·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·40	·643	·50
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 66
Number of times secondary beds were filled during month - - - - 66
Estimate of amount of tank liquor treated per cube yard per 24 hours - 69 gallons, 6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·02	·06	·02
Albuminoid nitrogen	·069	·098	·07
Nitric nitrogen	—	—	—
Chlorine	9·3	10·0	7·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·614	1·06	·80
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

Continuous Filter—

Number of hours filter worked during the month - - - - - 337
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons, 6 days per week.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·01	·03	·02
Albuminoid nitrogen	·033	·091	·055
Nitric nitrogen	—	—	—
Chlorine	7·0	10·6	7·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·46	·80	67
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples for the average = 18.

K. F. Campbell, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending December 2nd, 1903.

SEWAGE—

Average daily flow	gallons	Total rainfall	1·63 inches
Maximum daily flow	,,	Rainfall	,,
Minimum daily flow	,,	Rainfall	,,

Average Analysis of Sewage.

———	Best. (Sunday.)	Worst.	Average for Week-days.
Ammoniacal nitrogen	1·05	1·10	1·01
Albuminoid nitrogen	·328	·799	·584
Nitric nitrogen	—	—	—
Chlorine	5·6	12·4	12·1
Oxygen absorbed from $KMnO_4$ in 4 hours	2·39	12·8	9·81
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5·6 hours)		5,402,000 gallons.
Amount of sewage precipitated during the month		151,260,000 gallons
Amount of chemicals used during the month	Lime	18 tons 19 cwts.
	Copperas	12 tons 4 cwts.
Amount of sludge dealt with during the month		114,192 cubic feet = 3,312 tons.

Average Analysis of Precipitation Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	1·05	1·11	1·02
Albuminoid nitrogen	·331	·410	·345
Nitric nitrogen	—	—	—
Chlorine	9·0	13·6	11·6
Oxygen absorbed from $KMnO_4$ in 4 hours	3·7	6·79	5·34
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Sedimentation Tank—

Average flow through the tanks per 24 hours (10 hours)	131,000 gallons.
Amount of sewage treated in tanks during month	3,144,000 ,,
Amount of sludge dealt with from this process during month	62 tons.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	1·11	1·38	1·15
Albuminoid nitrogen	·279	·426	·374
Nitric nitrogen	—	—	—
Chlorine	9·1	13·1	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	3·89	6·71	5·43
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 70
Number of times secondary beds were filled during month - - - - 70
Estimate of amount of tank liquor treated per cube yard per 24 hours - 76 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·02	·18	·09
Albuminoid nitrogen	·064	·132	·089
Nitric nitrogen	·79	·56	·83
Chlorine	11·0	14·0	11·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·66	·96	·80
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 71
Number of times secondary beds were filled during month - - - - 71
Estimate of amount of tank liquor treated per cube yard per 24 hours - 68 gallons (6 days per week).

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·09	·15	·09
Albuminoid nitrogen	·081	·141	·118
Nitric nitrogen	1·03	·43	·53
Chlorine	9·0	11·9	11·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·76	1·40	1·31
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

Continuous Filter—

Number of hours filter worked during the month - - - - - 341
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons (6 days per week).

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·03	·26	·20
Albuminoid nitrogen	·095	·111	·108
Nitric nitrogen	·96	·73	·98
Chlorine	11·0	13·4	11·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·74	1·43	1·16
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 18.

K. F. Campbell, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending December 30th, 1903.

SEWAGE—

Average daily flow - - gallons - Total rainfall - - - - 2·15 inches.
Maximum daily flow - - „ - Rainfall - - - - - „
Minimum daily flow - - „ - Rainfall - - - - - „

Average Analysis of Sewage.

	Best. (Sunday.)	Worst.	Average. for Weekdays.
Ammoniacal nitrogen	·59	1·39	·94
Albuminoid nitrogen	·213	·680	·499
Nitric nitrogen	—	—	—
Chlorine	5·43	13·0	10·43
Oxygen absorbed from $KMnO_4$ in 4 hours	3·16	11·64	9·26
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 19.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5·6 hours) - - - - 5,391,000 gallons.
Amount of sewage precipitated during the month - - - - - 150,960,000 gallons.
Amount of chemicals used during the month { Lime - - - - - 17 tons 7 cwts.
{ Copperas - - - - 10 tons 13 cwts.
Amount of sludge dealt with during the month - - - - - 99,648 cubic feet = 2,890 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·59	1·38	·96
Albuminoid nitrogen	·197	·406	·287
Nitric nitrogen	—	—	—
Chlorine	6·6	12·1	9·6
Oxygen absorbed from $KMnO_4$ in 4 hours	2·90	6·31	4·61
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 12.

Sedimentation Tank—

Average flow through the tanks per 24 hours (10 hours) - - - - 131,000 gallons.
Amount of sewage treated in tanks during month - - - - - 3,144,000 gallons.
Amount of sludge dealt with from this process during month - - - ——

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·70	1·24	1·05
Albuminoid nitrogen	·204	·403	·306
Nitric nitrogen	—	—	—
Chlorine	6·4	13·1	10·4
Oxygen absorbed from $KMnO_4$ in 4 hours	2·80	6·69	5·16
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 1·7

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 43
Number of times secondary beds were filled during month - - - - 43
Estimate of amount of tank liquor treated per cube yard per 24 hours - 76 gallons, 6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·02	·15	·08
Albuminoid nitrogen	·056	·105	·07
Nitric nitrogen	·76	1·4	1·36
Chlorine	10·3	10·2	9·6
Oxygen absorbed from $KMnO_4$ in 4 hours	·57	1·09	·73
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 12.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 66
Number of times secondary beds were filled during month - - - - 66
Estimate of amount of tank liquor treated per cube yard per 24 hours - 67 gallons, 6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·07	·20	·94
Albuminoid nitrogen	·075	·12	·095
Nitric nitrogen	1·11	·66	·84
Chlorine	7·0	12·6	10·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·64	1·67	1·17
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

Continuous Filter—

Number of hours filter worked during the month - - - - - 325
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons, 6 days per week

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·20	·42	·32
Albuminoid nitrogen	·073	·163	·110
Nitric nitrogen	1·24	1·10	1·09
Chlorine	6·6	12·6	10·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·69	1·67	1·34
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 17.

K. F. Campbell, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending January 27th, 1904.

SEWAGE—

Average daily flow	gallons	Total rainfall	3·18 inches.
Maximum daily flow	„	Rainfall	„
Minimum daily flow	„	Rainfall	„

Average Analysis of Sewage.

	Best. (Sunday.)	Worst.	Average for Weekdays.
Ammoniacal nitrogen	·69	1·39	·94
Albuminoid nitrogen	·295	·828	·511
Nitric nitrogen	—	—	—
Chlorine	5·4	14·6	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	3·21	13·44	9·94
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours (5·4 hours)	5,635,000 gallons.
Amount of sewage precipitated during the month	157,770,000 „
Amount of chemicals used during the month { Lime	18 tons 16 cwts.
Amount of chemicals used during the month { Copperas	11 tons 11 cwts.
Amount of sludge dealt with during the month	101,232 cubic feet = 2,936 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·28	1·22	·88
Albuminoid nitrogen	·206	·393	·290
Nitric nitrogen	—	—	—
Chlorine	6·4	15·1	11·0
Oxygen absorbed from $KMnO_4$ in 4 hours	2·76	7·60	5·27
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Sedimentation Tanks—

Average flow through the tanks per 24 hours—	
From Dec. 31st to Jan. 13th (10 hours)	131,000 gallons.
From Jan. 14th to Jan. 27th (24 hours)	55,000 „
Amount of sewage treated in tanks during month	2,604,000 „
Amount of sludge dealt with from this process during month	

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·37	1·55	1·05
Albuminoid nitrogen	·193	·439	·293
Nitric nitrogen	—	—	—
Chlorine	7·0	16·0	11·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·14	7·79	5·39
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times primary beds were filled during month - - - - 69
Number of times secondary beds were filled during month - - - 69
Estimate of amount of tank liquor treated per cube yard per 24 hours - 76 gallons, 6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·00	·13	·08
Albuminoid nitrogen	·046	·091	·068
Nitric nitrogen	·99	·96	1·07
Chlorine	7·0	12·0	10·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·50	1·1	·77
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds after Sedimentation—

Number of times primary beds were filled during month - - - - 72
Number of times secondary beds were filled during month - - - - 72
Estimate of amount of tank liquor treated per cube yard per 24 hours - 66 gallons, 6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·02	·18	·09
Albuminoid nitrogen	·067	·116	·088
Nitric nitrogen	·87	·69	·74
Chlorine	7·9	14·0	10·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·71	1·79	1·20
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

Continuous Filter—

Number of hours filter worked during the month - - - - - 354
Amount of tank liquor treated per cube yard per 24 hours - - - - 132 gallons, 6 days per week.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·09	·59	·30
Albuminoid nitrogen	·066	·146	·104
Nitric nitrogen	·97	1·29	1·00
Chlorine	7·0	14·4	10·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·79	2·07	1·37
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 20.

K. F. Campbell, Borough Engineer.

HUDDERSFIELD—*continued.*

Month ending February 24th, 1904.

SEWAGE—

Average daily flow - - - - Total rainfall - - 5·29 inches.
Maximum daily flow - - - - Rainfall - - - -
Minimum daily flow - - - Rainfall - - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average for week-days.
Ammoniacal Nitrogen	(Sunday) ·29	·74	·57
Albuminoid Nitrogen	·155	·669	·384
Nitric Nitrogen	—	—	—
Chlorine	4·0	13·0	9·9
Oxygen absorbed from $KMnO_4$ in 4 hours	1·74	9·64	7·43
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - - - 5·5 hours. 5,580,000 gallons.
Amount of Sewage precipitated during the month - - - - - 156,240,000 gallons.
Amount of Chemicals used during the month - - - - - - { Lime, 20 tons 15 cwts. Copperas, 13 tons.
Amount of Sludge dealt with during the month - - - - - 129,801 cubic feet, equal to 3,764 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·26	·59	·52
Albuminoid Nitrogen	·131	·246	·187
Nitric Nitrogen	—	—	—
Chlorine	5·1	11·6	9 3
Oxygen absorbed from $KMnO_4$ in 4 hours	1·79	4·01	3·37
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - 55,000 gallons.
Amount of Sewage treated in Tanks during month - - - - 1,540,000 gallons.
Amount of Sludge dealt with from this process during month - - - February 5th, 77 tons.

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·40	·95	·56
Albuminoid Nitrogen	·144	·299	·198
Nitric Nitrogen	—	—	—
Chlorine	5·1	12·4	8 4
Oxygen absorbed from $KMnO_4$ in 4 hours	1·49	5·76	3·27
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after chemical treatment.

Number of times Primary Beds were filled during month - - - 19.

Number of times Secondary Beds were filled during month - - - 72.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 76 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·00	·05	·01
Albuminoid Nitrogen	·046	·066	·054
Nitric Nitrogen	·86	1·44	1·16
Chlorine	6·9	10·9	9·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·40	·81	·57
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

Contact Beds after Septic treatment.

Number of times Primary Beds were filed during month - - - 66.

Number of times Secondary Beds were filled during month - - - 66.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 65 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·01	·06	02
Albuminoid Nitrogen	·053	·095	·063
Nitric Nitrogen	1·40	·36	·97
Chlorine	6·0	11·9	8·4
Oxygen absorbed from $KMnO_4$ in 4 hours	·47	1·41	·81
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

Continuous Filter.

Number of hours Filter worked during the month - - - - - 319.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·10	·34	·13
Albuminoid Nitrogen	·056	·098	·073
Nitric Nitrogen	1·44	·56	1·06
Chlorine	5·6	12·0	8·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·54	1·89	·96
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

REMARKS.—

HUDDERSFIELD—*continued.*

SEWAGE— Month ending March 30th, 1904. (5 weeks.)

Average daily flow	-	Total rainfall - - - -	2·44 inches
Maximum daily flow - -		Rainfall - - - - -	
Minimum daily flow - -	-	Rainfall - - - - -	

Average Analysis of Sewage

	Best.	Worst.	Average for week-days.
	(Sunday).		
Ammoniacal Nitrogen - - - - - - - - -	·99	1·14	1·03
Albuminoid Nitrogen - - - - - - - - -	·321	·664	·573
Nitric Nitrogen - - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	6·1	13·0	12·6
Oxygen absorbed from $KMnO_4$ in 4 hours - - - - -	3·76	13·4	10·57
Dissolved Oxygen taken up in 24 hours - - - - -	—	—	—
Suspended Solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 25.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - -	5·6 hours. 5,481,000 gallons.
Amount of Sewage precipitated during the month - - - - -	153,468,000 gallons.
Amount of Chemicals used during the month - - - - - -	Lime, 19 tons 10 cwts. Copperas, 11 tons 18 cwts.
Amount of Sludge dealt with during the month - - - - - -	112,501 cubic feet = to 3,262 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - -	·67	1·22	1·00
Albuminoid Nitrogen - - - - - - - - -	·230	·472	·293
Nitric Nitrogen - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	3·8	6·1	5·19
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	10·0	14·00	11·00
Dissolved Oxygen taken up in 2 hours - - - -	—	—	—
Suspended Solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 24.

SEPTIC TANKS—

Average flow through the Tanks per 24 hours - - - - - -	55,000 gallons.
Amount of Sewage treated in Tanks during month - - - - -	1,540,000 gallons.
Amount of Sludge dealt with from this procees during month - - -	

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	·64	1·90	1·14
Albuminoid Nitrogen - - - - - - - - -	·221	1·302	·284
Nitric Nitrogen - - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - - -	8·6	12·6	10·7
Oxygen absorbed from $KMnO_4$ in 24 hours - - - -	3·96	6·16	5·07
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—
Suspended Solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 25.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after chemical treatment—

Number of times Primary Beds were filled during month - - - 88

Number of times Secondary Beds were filled during month - - - - 88

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 76 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·04	·07	·07
Albuminoid Nitrogen	·044	·091	·069
Nitric Nitrogen (and nitrous)	—	·80	·93
Chlorine	8·0	12·4	10·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·47	1·27	·94
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 24.

Contact Beds after Septic treatment—

Number of times Primary Beds were filled during month - - - - 90

Number of times Secondary Beds were filled during month - - - - 90

Estimate amount of Tank Liquor treated per cube yard per 24 hours - - 64 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·07	·13	·09
Albuminoid Nitrogen	·073	·124	·087
Nitric Nitrogen	—	·54	·70
Chlorine	7·6	12·4	10·6
Oxygen absorbed from $KMnO_4$ in 4 hours	·71	1·49	1·26
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 25.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 429 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·28	·34	·32
Albuminoid Nitrogen	078	·114	·090
Nitric Nitrogen	—	·83	·97
Chlorine	7·6	9·9	10·6
Oxygen absorbed from $KMnO_4$ in 4 hours	·84	1·74	1·29
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 25.

REMARKS—

HUDDERSFIELD—*continued.*

SEWAGE— Month ending April 27th, 1904.

Average daily flow - - - - - Total rainfall - - - 2·46 inches.

Maximum daily flow - - - - - Rainfall - - - - -

Minimum daily flow - - - - - Rainfall - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average for Weekdays.
	Monday.		
Ammoniacal Nitrogen	1·18	1·56	1·18
Albuminoid Nitrogen	·331	·856	·587
Nitric Nitrogen	—	—	—
Chlorine	5·1	17·9	12·7
Oxygen absorbed from $KMnO_4$ in 4 hours	3·29	14·29	10·59
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - - - 5·7 hours. 5,360,000 gallons.

Amount of Sewage precipitated for the month - - - - - - 150,080,000 gallons.

Amount of Chemicals used during the month - - - - - { Lime, 19 tons 5 cwt. Copperas, 11 tons 8 cwt.

Amount of Sludge dealt with during the month - - - - - - 152,010 cubic feet equal to 4,408 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours		—	—
Suspended Solids	—	—	—

Number of samples analysed for the average =

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - - 24 hours. 55,000 gallons

Amount of Sewage treated in Tanks during month - - - - - 1,540,000 gallons

Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·75	1·51	1·23
Albuminoid Nitrogen	·204	·381	·240
Nitric Nitrogen	—	—	—
Chlorine	8·4	12·6	12·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·64	7·71	6·60
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 15.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after chemical treatment—

Number of times Primary Beds were filled during month - - - - 24.

Number of times Secondary Beds were filled during month - - - 24.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 78 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average =

Contact Beds after Septic treatment—

Number of times Primary Beds were filled during month - - - - 65.

Number of times Secondary Beds were filled during month - - 65.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 62 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·08	·14	·11
Albuminoid Nitrogen	·057	·124	·091
Nitric Nitrogen	·87	—	·59
Chlorine	9·6	14·1	11·9
Oxygen absorbed from $KMnO_4$ in 4 hours	1·29	1·97	1·59
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 15.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 306 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·13	·42	·26
Albuminoid Nitrogen	·067	·098	·077
Nitric Nitrogen	1·10	·76	1·04
Chlorine	7·9	15·1	11·4
Oxygen absorbed from $KMnO_4$ in 4 hours	1·10	2·11	1·40
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 12.

REMARKS—

HUDDERSFIELD—*continued.*

Month ending May 25th, 1904.

SEWAGE—

Average daily flow - - - - Total rainfall - - - 1·68 inches.

Maximum daily flow - - - - Rainfall - - - - -

Minimum daily flow - - - - Rainfall - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average for week-days.
Ammoniacal Nitrogen	(Tuesday.) 1·76	1·67	1·42
Albuminoid Nitrogen	·413	1·102	·717
Nitric Nitrogen	—	—	—
Chlorine	7·0	13·0	14·4
Oxygen absorbed from $KMnO_4$ in 4 hours	2·61	14·00	12 11
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - - 5·6 hours. 5,410,000 gallons.

Amount of Sewage precipitated during the month - - - - - 151,480,000 gallons.

Amount of Chemicals used during the month - - - { Lime, 20 tons 2 cwt. Copperas, 15 tons 0 cwt.

Amount of Sludge dealt with during the month - - - - 139,801 cubic feet equal to 4,054 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·51	1·41	1·41
Albuminoid Nitrogen	·288	·368	·323
Nitric Nitrogen	—	—	—
Chlorine	6·6	15·00	13·6
Oxygen absorbed from $KMnO_4$ in 4 hours	3·16	7·10	6·20
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - - 24 hours. 55,000 gallons

Amount of Sewage treated in Tanks during month - - - - - 1,540,000 gallons.

Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·41	1·41	1·48
Albuminoid Nitrogen	·253	·430	·319
Nitric Nitrogen	—	—	—
Chlorine	10·0	13·1	13·7
Oxygen absorbed from $KMnO_4$ in 4 hours	4·44	7·36	6·41
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after chemical treatment—

Number of times Primary Beds were filled during month - - - 61

Number of times Secondary Beds were filled during month - - 61

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 78 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·05	·11	·08
Albuminoid Nitrogen	·057	·097	·078
Nitric Nitrogen	1·44	·57	91
Chlorine	11·0	16·1	13·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·96	1·36	1·18
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

Contact Beds after Septic treatment—

Number of times Primary Beds were filled during month - - - 54

Number of times Secondary Beds were filled during month - - 54

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 60 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·12	·27	·14
Albuminoid Nitrogen	·089	·140	·109
Nitric Nitrogen	·26	·14	·41
Chlorine	14·4	13·9	13·9
Oxygen absorbed from $KMnO_4$ in 4 hours	1·39	2·29	1·83
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 15

Continuous Filter—

Number of hours Filter worked during the month - - - - - 324 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - 132 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·18	·57	·27
Albuminoid Nitrogen	·069	·103	·085
Nitric Nitrogen	1·21	·69	1·03
Chlorine	14·9	15·0	13·7
Oxygen absorbed from $KMnO_4$ in 4 hours	1·26	2·00	1·40
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 17.

REMARKS—

HUDDERSFIELD—*continued.*

Month ending June 22nd, 1904.

SEWAGE—

Average daily flow - - - - Total rainfall - - - - 2·53 inches.

Maximum daily flow - - - - Rainfall - - - - -

Minimum daily flow - - - - Rainfall - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average for week-days.
Ammoniacal Nitrogen	(Sunday.) ·15	1·26	1·29
Albuminoid Nitrogen	·328	·775	·666
Nitric Nitrogen	—	—	—
Chlorine	6 6	16·0	13·9
Oxygen absorbed from $KMnO_4$ in 4 hours	2·89	12·51	11·57
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 16.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - - - 6·3 hours. 4,821,000 gallons.

Amount of Sewage precipitated during the month - - - - - 134,988,000, gallons.

Amount of Chemicals used during the month - - - - - - { Lime, 19 tons 14 cwts. Copperas, 13 tons 10 cwts.

Amount of Sludge dealt with during the month - - - - - 143,000 cubic feet, equal to 4,147 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·15	1·44	1·30
Albuminoid Nitrogen	·239	·310	·286
Nitric Nitrogen	—	—	—
Chlorine	13·0	17·1	12·1
Oxygen absorbed from $KMnO_4$ in 4 hours	5·01	5·79	5·09
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 11.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - 24 hours. 55,000 gallons.

Amount of Sewage treated in Tanks during month - - - - 1,540,000 gallons.

Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·44	1·48	1·42
Albuminoid Nitrogen	·272	·357	·320
Nitric Nitrogen	—	—	—
Chlorine	8·4	16·6	11·3
Oxygen absorbed from $KMnO_4$ in 4 hours	4·99	6·60	5·77
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 8.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after chemical treatment—

Number of times Primary Beds were filled during month - - - - 66

Number of times Secondary Beds were filled during month - - - 66.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 77 gallons, 6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·08	·07	·07
Albuminoid Nitrogen	·05	·069	·052
Nitric Nitrogen	·66	—	·67
Chlorine	12·1	11·6	12·3
Oxygen absorbed from $KMnO_4$ in 4 hours	·81	·94	1·04
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 11.

Contact Beds after Septic treatment—

Number of times Primary Beds were filled during month - - - 46.

Number of times Secondary Beds were filled during month - - - 46.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 60 gallons, 6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·12	·12	·11
Albuminoid Nitrogen	·091	·141	·121
Nitric Nitrogen	—	—	—
Chlorine	12·4	11·4	11·3
Oxygen absorbed from $KMnO_4$ in 4 hours	1·50	1·86	1·81
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 8.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 365.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons, 6 days per week.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·08	·28	·16
Albuminoid Nitrogen	·044	·09	·064
Nitric Nitrogen	—	1·37	·97
Chlorine	10·57	9·4	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·77	1·48	1·11
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 13.

REMARKS—

HUDDERSFIELD—*continued.*

SEWAGE— Month ending July 20th, 1904.

Average daily flow - - - - -		Total rainfall - - -	·81 inches.
Maximum daily flow - - - - -		Rainfall - - - -	
Minimum daily flow - - - - -		Rainfall - - - -	

Average Analysis of Sewage.

——	Best.	Worst.	Average for Week-days.
Ammoniacal Nitrogen - - - - - - - - -	(Sunday.) 2·58	1·88	1·50
Albuminoid Nitrogen - - - - - - - - -	·419	1·128	·824
Nitric Nitrogen - - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	10·7	21·1	16·6
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	7·39	16·31	13·74
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—
Suspended Solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 18.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - -	6·9 hours. 4,390,000 gallons.
Amount of Sewage precipitated during month - - - - - -	122,920,000 gallons.
Amount of Chemicals used during the month - - - - - -	Lime, 21 tons 19 cwt. Copperas, 15 tons 0 cwt.
Amount of Sludge dealt with during the month - - - - -	136,500 cubic feet, equal to 3,958 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - - -	—	—	—
Nitric Nitrogen - - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	—	—	—
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—
Suspended Solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average =

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - -	24 hours. 55,000 gallons.
Amount of Sewage treated in Tanks during month - - - -	1,540,000 gallons.
Amount of Sludge dealt with from this process during month - -	120 tons.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - - -	2·13	1·57	1·46
Albuminoid Nitrogen - - - - - - - - -	·341	·550	·446
Nitric Nitrogen - - - - - - - - - -	—	—	—
Chlorine - - - - - - - - - - -	12·0	15·43	14·7
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	6·94	11·76	9·54
Dissolved Oxygen taken up in 24 hours - - - -	—	—	—
Suspended Solids - - - - - - - - - -	—	—	—

Number of samples for the average = 14.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical treatment—

Number of times Primary Beds were filled during month - - - - 6.

Number of times Secondary Beds were filled during month - - - 6.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 77 gallons—6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Nitric Nitrogen	—	—	—
Chlorine	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = .

Contact Beds after Septic treatment—

Number of times Primary Beds were filled during month - - 64.

Number of times Secondary Beds were filled during month - - - 64.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 59 gallons—6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·23	·16	·22
Albuminoid Nitrogen	·095	·156	·115
Nitric Nitrogen	·23	·13	·30
Chlorine	12·1	17·1	14·4
Oxygen absorbed from $KMnO_4$ in 4 hours	1·59	2·34	1·93
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 14.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 328 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·50	·18	·35
Albuminoid Nitrogen	·082	·102	·091
Nitric Nitrogen	·86	·86	·64
Chlorine	11·6	16·4	14·9
Oxygen absorbed from $KMnO_4$ in 4 hours	1·36	2·03	1·61
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 13.

REMARKS:—

HUDDERSFIELD—*continued.*

SEWAGE— Month ending August 17th, 1904.

Average daily flow - - - - Total rainfall - - - - - 7·90 inches.

Maximum daily flow - - - - Rainfall

Minimum daily flow - - - - Rainfall

Average Analysis of Sewage.

	Best.	Worst.	Average for week-days.
Ammoniacal Nitrogen	(Sunday). 1·31	1·39	·97
Albuminoid Nitrogen	·315	·893	·557
Nitric Nitrogen	—	—	—
Chlorine	9·9	21·0	14·6
Oxygen absorbed from $KMnO_4$ in 4 hours	2·86	16·49	9·87
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - - - 8·0 hours. 3,802,000 gallons.

Amount of Sewage precipitated during the month - - - - - 106,467,000 gallons.

Amount of Chemicals used during the month - - - - - - { Lime, 14 tons 18 cwts. Copperas, 8 tons 17 cwts

Amount of Sludge dealt with during the month - - - - - 117,936 cubic feet = to 3,420 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·56	1·84	1·00
Albuminoid Nitrogen	·155	518	·282
Nitric Nitrogen	—		—
Chlorine	7·0	18 9	13·1
Oxygen absorbed from $KMnO_4$ in 4 hours	2·76	9·00	4·60
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 16.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - - 24 hours. 55,000 gallons.

Amount of Sewage treated in Tanks during month - - - - - 1,540,000 gallons.

Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·49	1·72	1 09
Albuminoid Nitrogen	·157	·357	·261
Nitric Nitrogen	—	—	—
Chlorine	8·1	18·9	13·9
Oxygen absorbed from $KMnO_4$ in 4 hours	2·80	9·29	4·96
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical treatment—

Number of times Primary Beds were filled during month - - - - 69

Number of times Secondary Beds were filled during month - - - 69

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 76 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·00	·22	·04
Albuminoid Nitrogen	·033	·110	·064
Nitric Nitrogen	1·14	1·39	1·33
Chlorine	8·1	19·0	13·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·54	1·66	·87
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 16.

Contact Beds after Septic treatment—

Number of times Primary Beds were filled during month - - - - 69

Number of times Secondary Beds were filled during month - - - 69

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 58 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·07	·23	0·8
Albuminoid Nitrogen	·066	·130	·096
Nitric Nitrogen	·89	·24	·63
Chlorine	8·9	18·0	13·7
Oxygen absorbed from $KMnO_4$ in 4 hours	·96	2·20	1·53
Dissolved Oxygen taken in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 343 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·02	·26	·08
Albuminoid Nitrogen	·033	·093	·062
Nitric Nitrogen	1·04	·99	·91
Chlorine	8·6	18·0	13·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·67	1·53	1·01
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

REMARKS—

HUDDERSFIELD—*continued.*

Month ending September 14th, 1904.

SEWAGE—

Average daily flow - - - - - Total rainfall - - - - 2·66 inches

Maximum daily flow- - - - - Rainfall - - - - -

Minimum daily flow- - - - Rainfall - - - - -

Average Analysis of Sewage.

	Best.	Worst.	Average for weekdays.
	(Sunday.)		
Ammoniacal Nitrogen	1·11	1·56	1·03
Albuminoid Nitrogen	·262	1·011	·604
Nitric Nitrogen	—	—	—
Chlorine	6·9	12·6	12·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·06	13·56	10·21
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through tanks per 24 hours - - - - - - 6·9 hours. 4,374,000 gallons.

Amount of Sewage precipitated during the month - - - - - 122,469, 000 gallons.

Amount of chemicals used during the month - - - - - { Lime, 15 tons 11 cwts. Copperas, 8 tons 17 cwts.

Amount of Sludge dealt with during the month - - - 100,512 cubic feet, equal to 2,915 tons.

Average Analysis of Precipitation Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·78	1·60	1·16
Albuminoid Nitrogen	·187	·439	·297
Nitric Nitrogen	—	—	—
Chlorine	6·0	15·0	11·7
Oxygen absorbed from $KMnO_4$ in 4 hours	2·49	7·54	5·87
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - - 24 hours. 55,000 gallons.

Amount of Sewage treated in Tanks during month - - - - - 1,540,000 gallons.

Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·98	1·73	1·25
Albuminoid Nitrogen	·167	·381	·268
Nitric Nitrogen	—	—	—
Chlorine	6·0	12·6	11·1
Oxygen absorbed from $KMnO_4$ in 4 hours	2·19	7·60	5·60
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical Treatment—

Number of times Primary Beds were filled during month - - - - 69.

Number of times Secondary Beds were filled during month - - - 69.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 76 gallons—6 days perweek.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·00	·05	·05
Albuminoid Nitrogen	·041	·097	·074
Nitric Nitrogen	—	·64	·79
Chlorine	6·0	13·6	11·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·57	1·61	1·43
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 18.

Contact Beds after Septic Treatment—

Number of times Primary Beds were filled during month - - - 72.

Number of times Secondary Beds were filled during month - - - 72.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 57 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·05	·22	·12
Albuminoid Nitrogen	·056	·136	·091
Nitric Nitrogen	—	—	·39
Chlorine	7·1	15·6	11·0
Oxygen absorbed from $KMnO_4$ in 4 hours	66	2·16	1·37
Dissolved Oxygen taken up in 24 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 19.

Continuous Filter—

Number of hours filter worked during the month - - - - - 362 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·01	·29	·12
Albuminoid Nitrogen	·041	·090	·059
Nitric Nitrogen	—	1·17	1·07
Chlorine	6·0	13·0	11·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·49	1·63	·96
Dissolved Oxygen taken up in 84 hours	—	—	—
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

REMARKS —

HUDDERSFIELD—*continued.*

Month ending October 12th, 1904.

SEWAGE—

Average daily flow - - - - - Total rainfall - - - - - ·79 inches.
Maximum daily flow - - - - Rainfall - - - - - -
Minimum daily flow - - - - Rainfall - - - - - -

Average Analysis of Sewage.

——	Best.	Worst.	Average for weekdays.
Ammoniacal Nitrogen	(Sunday.) ·91	1·48	1·51
Albuminoid Nitrogen	·324	1·180	·735
Nitric Nitrogen	—	—	—
Chlorine	5·0	19·1	13·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·19	14·49	11·74
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 19.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - 6·4 hours. 4,770,000 gallons.
Amount of Sewage precipitated during the month - - - 133,557,000 gallons.
Amount of Chemicals used during the month - - - - { Lime, 16 tons 11 cwts. / Copperas, 10 tons 3 cwts.
Amount of Sludge dealt with during the month - - - 100,368 cubic feet, equal to 2,911 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·21	1·51	1·57
Albuminoid Nitrogen	·197	·413	·338
Nitric Nitrogen	—	—	—
Chlorine	5·6	17·0	12·0
Oxygen absorbed from $KMnO_4$ in 4 hours	3·10	8·11	6·41
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 9.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - 24 hours. 55,000 gallons.
Amount of Sewage treated in Tanks during month - - - - 1,540,000 gallons.
Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·57	1·90	1·76
Albuminoid Nitrogen	·249	·521	369
Nitric Nitrogen	—	—	—
Chlorine	6·9	16·0	12·0
Oxygen absorbed from $KMnO_4$ in 4 hours	3·91	8·54	6·80
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 19.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical Treatment—

Number of times Primary Beds were filled during month - - - - 36.

Number of times Secondary Beds were filled during month - - - 36.

Estimate of amount of Tank liquor treated per cube yard per 24 hours - 76 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·08	·13	·09
Albuminoid Nitrogen	·066	·108	·090
Nitric Nitrogen	—	—	—
Chlorine	10·7	14·0	12·0
Oxygen absorbed from $KMnO_4$ in 4 hours	·84	1·56	1·26
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 9.

Contact Beds after Septic Treatment—

Number of times Primary Beds were filled during month - - - 69.

Number of times Secondary Beds were filled during month - - - 69.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 56 gallons—6 days per week.

Average Analysis of Filter Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·09	·20	·16
Albuminoid Nitrogen	·091	·111	·108
Nitric Nitrogen	—	—	—
Chlorine	9·6	14·9	12·3
Oxygen absorbed from $KMnO_4$ in 4 hours	·94	2·13	1·69
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 19.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 350 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons.—6 days per week.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·27	·42	·29
Albuminoid Nitrogen	·073	·089	·075
Nitric Nitrogen	—	—	—
Chlorine	7·1	13·9	12·1
Oxygen absorbed from $KMnO_4$ in 4 hours	·80	1·89	1·27
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 20.

March 31st, 1905.

K. F. Campbell, M.Inst.C.E., Engineer.

P. Coward, Chemist.

HUDDERSFIELD—*continued.*

SEWAGE— Month ending November 9th, 1904.

Average daily flow - - - - Total rainfall - - - - 1·91 inches
Maximum daily flow - - - - Rainfall - - - - -
Minimum daily flow - - - - Rainfall - - - -

Average Analysis of Sewage.

——	Best.	Worst.	Average for weekdays
Ammoniacal Nitrogen	(Sunday.) 1·89	1·89	1·64
Albuminoid Nitrogen	·492	1·365	·778
Nitric Nitrogen	—	—	—
Chlorine	9·0	13·4	14·6
Oxygen absorbed from $KMnO_4$ in 4 hours	6·79	15·11	13·41
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 20.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours - - - - - 6·6 hours. 4,575,000 gallons.
Amount of Sewage precipitated during the month - - - - - 128,112,000 gallons.
Amount of Chemicals used during the month - - - - - { Lime, 17 tons 7 cwts. / Copperas, 10 tons 1 cwt.
Amount of Sludge dealt with during the month - - - 104,832 cubic feet, equal to 3,040 tons.

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	·91	2·05	1·80
Albuminoid Nitrogen	·288	·480	·399
Nitric Nitrogen	—	—	—
Chlorine	8.6	14·9	13·9
Oxygen absorbed from $KMnO_4$ in 4 hours	5·69	9·56	8·20
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 15.

Septic Tanks—

Average flow through the Tanks per 24 hours - - - - - - 24 hours. 55,000 gallons.
Amount of Sewage treated in Tanks during month - - - - - 1,540,000 gallons.
Amount of Sludge dealt with from this process during month - - -

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·39	2·13	2·05
Albuminoid Nitrogen	·397	·533	·430
Nitric Nitrogen	—	—	—
Chlorine	10·6	14·0	13·4
Oxygen absorbed from $KMnO_4$ in 4 hours	7·14	10·09	8·73
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 20.

HUDDERSFIELD—*continued.*

FILTERS—

Contact Beds after Chemical Treatment—

Number of times Primary Beds were filled during month - - - - - 55.

Number of times Secondary Beds were filled during month - - - 55.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 77 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·00	·13	·13
Albuminoid Nitrogen	·057	·135	·108
Nitric Nitrogen	1·00	1·21	·99
Chlorine	10·4	13·0	13·7
Oxygen absorbed from $KMnO_4$ in hours	1·06	1·90	1·74
Dissolved Oxygen taken up in 24 hours	—	—	

Number of samples analysed for the average = 15.

Contact Beds after Septic Treatment—

Number of times Primary Beds were filled during month - - - - 19.

Number of times Secondary Beds were filled during month - - - - 19.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 54 gallons—6 days per week.

Average Analysis of Filter Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·20	·33	·22
Albuminoid Nitrogen	·089	·122	·104
Nitric Nitrogen	—	—	—
Chlorine	12·4	15·0	13·6
Oxygen absorbed from $KMnO_4$ in 4 hours	1·46	2·21	1·87
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 5.

Continuous Filter—

Number of hours Filter worked during the month - - - - 345 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	·09	49	·37
Albuminoid Nitrogen	·057	·111	087
Nitric Nitrogen	1·13	1·06	1·41
Chlorine	10·4	14·6	13·6
Oxygen absorbed from $KMnO_4$ in 4 hours	1·10	1·93	1·57
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 20.

REMARKS—

K. F. Campbell, M.Inst.C.E., Engineer.
P. Coward, Chemist.

March 31st, 1905.

HUDDERSFIELD—*continued.*

SEWAGE— Month ending December 7th, 1904.

Average daily flow		Total rainfall	1·68 inches.
Maximum daily flow		Rainfall	
Minimum daily flow		Rainfall	

Average Analysis of Sewage.

——	Best.	Worst.	Average for weekdays.
Ammoniacal Nitrogen	1·52	1·77	1·41
Albuminoid Nitrogen	·574	·615	·671
Nitric Nitrogen	—	—	—
Chlorine	—	14·4	14·4
Oxygen absorbed from $KMnO_4$ in 4 hours	11·49	14·89	12·94
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 11.

TANKS—

Precipitation Tanks—

Average flow through Tanks per 24 hours	6·4 hours. 4,764,000 gallons.
Amount of Sewage precipitated during the month	133,380,000 gallons.
Amount of Chemicals used during the month	Lime, 15 tons 16 cwt. Copperas, 9 tons 3 cwts.
Amount of Sludge dealt with during the month	94,320 cubic feet, equal to 2,735 tons

Average Analysis of Precipitation Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·08	1·60	1·62
Albuminoid Nitrogen	·354	·451	·411
Nitric Nitrogen	—	—	—
Chlorine	12·4	17·6	13·7
Oxygen absorbed from $KMnO_4$ in 4 hours	6·81	9·14	7·91
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 10.

Septic Tanks—

Average flow through the Tanks per 24 hours	24 hours. 55,000 gallons.
Amount of Sewage treated in Tanks during month	1,540,000 gallons.
Amount of Sludge dealt with from this process during month	128 tons.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·51	·20	1·66
Albuminoid Nitrogen	·308	·443	·399
Nitric Nitrogen	—	—	—
Chlorine	11·4	14·0	13·9
Oxygen absorbed from $KMnO_4$ in 4 hours	6·61	9·70	8·01
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average=11.

FILTERS—

Contact Beds after Chemical Treatment—

Number of times Primary Beds were filled during month - - - - 63.

Number of times Secondary Beds were filled during month - - - 6.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 76 gallons—6 days per week.

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·13	·13	·13
Albuminoid Nitrogen	·054	·108	·088
Nitric Nitrogen	—	·83	·86
Chlorine	11·9	15·0	12·9
Oxygen absorbed from $KMnO_4$ in 4 hours	1·19	1·91	1·56
Dissolved Oxygen taken up in 24 hours		—	—

Number of samples analysed for the average = 10.

Contact Beds after Septic Treatment—

Number of times Primary Beds were filled during month - - - - 64.

Number of times Secondary Beds were filled during month - - - 64.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - 59 gallons—6 days per week.

Average Analysis of Filter Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·21	·21	·19
Albuminoid Nitrogen	·126	·131	·125
Nitric Nitrogen	—	—	—
Chlorine	11·9	15·0	14·0
Oxygen absorbed from $KMnO_4$ in 4 hours	1·70	2·54	2·04
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 8.

Continuous Filter—

Number of hours Filter worked during the month - - - - - 331 hours.

Amount of Tank Liquor treated per cube yard per 24 hours - - - 132 gallons—6 days per week.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	·13	·70	·32
Albuminoid Nitrogen	·053	·111	·078
Nitric Nitrogen	1·09	1·16	—
Chlorine	11·4	11·1	13·3
Oxygen absorbed from $KMnO_4$ in 4 hours	1·00	2·01	1·56
Dissolved Oxygen taken up in 24 hours	—	—	—

Number of samples analysed for the average = 11.

REMARKS—

K. F. Campbell, M.Inst.C.E., Engineer.
P. Coward, Chemist.

March 31st, 1905.

SEVENTY-FOURTH DAY.

Thursday, 11th May, 1905.

PRESENT.

The Right Honourable the Earl of Iddesleigh (*Chairman*) presiding.
Major-General Constantine Phipps Carey, C.B., R.E.
Colonel T. W. Harding, J.P.
Sir William Ramsay, K.C.B., F.R.S.
Mr. W. H. Power, C.B., F.R.S.
Mr. T. J. Stafford, F.R.C.S.I.

Mr. F. J. Willis (*Secretary*).

ALSO PRESENT.

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. W. H. Harrison, M.Sc., called in ; and Examined.

Mr. W. H. Harrison, M.Sc.

11 May 1905.

21946. (*Chairman.*) You are Mr. W. H. Harrison, Chemist to the Leeds Corporation Sewage Works ?—Yes.

21947. And you have come before us to-day to give evidence with regard to your experience of the treatment of sewage, with special reference to the Leeds Sewage Works ?—Yes.

21948. What is the general system of sewage treatment at Leeds ?—The bulk of the sewage is treated by precipitation in continuous settlement tanks, and a small proportion is treated in septic tanks, and by means of various comparatively small bacteriological filters.

21949. What is the population draining to the Leeds Works ?—The population of Leeds at the last census (1901) was 428,968, and the estimated population in June, 1904, was 450,142. The Sewage from the whole drains to Knostrop Sewage Works, with the exception of a small portion which drains to the Rodley Works.

21950. What is the system of drainage ? That is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent ?—Storm water and the ordinary sewage both enter the same system of sewers.

21951. Is there any infiltration of subsoil water into the sewers ?—There is some infiltration of subsoil water, but its presence is only felt after long periods of wet weather. At ordinary times the amount entering the sewers is very small.

21952. What is the water supply per head, and from what source does it come ?—The present water supply is 36 gallons per head of population per day, being practically 16,000,000 gallons per day, *i.e.*, almost equal to the dry weather flow of sewage. The collecting ground for the Leeds water supply is the area draining into the river Washburn, a tributary of the Wharfe.

21953. Is it hard or soft water—The water is soft. The total hardness is equal to 5·0 parts of $CaCO_3$ per 100,000.

21954. What is the drainage area of the part of the town which is sewered ?—The City of Leeds has an area of 21,572 acres and most of this is drained. Part of the area, comprising 1,500 acres, is tributary to Rodley.

21955. What proportion of the population use pail closets or middens and what proportion use water-closets ? —About three-fourths of the population use water closets or trough (water) closets, and the rest privies. The latter are being replaced by water closets which are now compulsory in new buildings.

21956. Has the flow of sewage to your works been gauged ? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather, in winter, and in summer ?—The average of gaugings taken 3 years ago in dry weather showed the sewage flow to be between 15-16 million gallons per 24 hours. There is no great difference between the dry weather flow in summer and in winter.

21957. What is the maximum dry weather rate of flow and at what hour does this occur ?—The maximum dry weather rate of flow is about 26,000,000 gallons per 24 hours, and occurs usually about 10 a.m.

21958. What is the minimum dry weather rate of flow, and at what hour does it occur ?—The minimum flow occurs about 4 a.m. and is at the rate of 10,500,000 gallons per 24 hours. The hourly variation in the rate of flow during the 24 hours is as follows :—

Time	Rate of Flow in Galls. per 24 hours.
7 a.m.	11,300,000
8 a.m.	12,000,000
9 a.m.	12,000,000
10 a.m.	26,200,000
11 a.m.	22,500,000
12 (noon)	22,500,000
1 p.m.	22,500,000
2 p.m.	19,900,000
3 p.m.	19,100,000
4 p.m.	19,100,000
5 p.m.	19,900,000
6 p.m.	23,400,000
7 p.m.	20,800,000
8 p.m.	20,800,000
9 p.m.	19,900,000
10 p.m.	19,000,000
11 p.m.	19,000,000
12 (midnight)	19,000,000
1 a.m.	11,300,000
2 a.m.	11,300,000
3 a.m.	11,300,000
4 a.m.	10,600,000
5 a.m.	12,000,000
6 a.m.	12,000,000
Average	17,300,000

21959. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued ?—The main outfall sewer has a maximum capacity of 60 million gallons per 24 hours and a very slight rainfall (about $\frac{1}{20}$ in. per hour fills it to its full capacity. Thus the maximum wet weather flow is often reached during the course of a year, the duration of any such flow being coincident with the continuance of the rainfall.

21960. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source ?—The infiltration of subsoil water into the sewers varies with the state of the weather, *i.e.*, in dry weather practically no subsoil water is present, but after a heavy rainfall it is present for some time. During these latter periods the maximum amount entering the sewers will be about three million gallons per day.

Mr. W. H. Harrison, M.Sc.

11 May 1905.

21961. How many gallons of trade effluents enter the sewers daily, and what is the nature of these effluents? If you have analytical figures, please give them?—One third of the water supply is used for trade purposes and practically the whole of this enters the sewers. In addition some few works possessing their own wells have access to the sewers. The total amount received will be about 6 million gallons per day. In the City of Leeds will be found representatives of most trades and manufacturing processes, so that together they produce a very complex mixture of trade refuse. The chief effluents however are those from Tanneries, Dye-Works, Copper and Galvanizing Works, Vitriol Works, Ammonia Works, etc., and some Wool-scouring Works.

One trade effluent from an Ammonia Works gave the following analysis:—

	Per cent.
Loss on ignition	42
CaO (free in solution)	5
CaO (in combination)	30
Cl as chloride	17

These figures are calculated on the dry solids. This liquid exerted a strong precipitating action on sewage and contained solids in solution to the extent of 2,220 parts per 100,000. Another effluent from a Vitriol Works contained 14,500 parts of $FeSO_4$ per 100,000 as well as very large quantities of Na_2SO_4 and NaCl. Another liquid which has come under examination contained 12 per cent. of free sulphuric acid and As_2S_3 in suspension to the extent of 1,530 parts per 100,000.

21962. Have the Corporation framed any rules for the reception of trade effluents into the sewers?—The admission of trade refuse to the sewers is conditional upon (*a*). The adoption of efficient means for removing the solids from the refuse; (*b*.) The discharge to be so regulated as as to be spread equally over the 24 hours; (*c*.) The provision of an inspection manhole.

*21962. Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume, or otherwise?—The experience at Leeds is that if the trade effluents are free from suspended solids, are admitted at a uniform rate over the 24 hours, and are not great in volume compared to the domestic sewage, no difficulty is experienced in treating the mixed sewage. Strong dye-liquors if treated on filters without the previous use of a septic tank, discolour the filtrate, and cause inefficient oxidation and æration. This is not apparent when they are diluted by being discharged evenly over the 24 hours, especially when septic tanks are used. The iron liquors received into the Leeds sewers are chiefly in the ferrous state, and when discharged in bulk into the sewers at irregular intervals, a large proportion of the iron reaches the works in the reduced condition. In this state, having a great affinity for oxygen, the filtrate is usually deteriorated in quality and the nitrification values are low. The filtrates from contact beds are strongly yellow and often separate out flocculent basic iron-compounds producing a very unsightly condition. A large part of the iron is separated out of solution in the filters and cements the bed material into large impervious masses. With trickling filters there is practically no iron present in solution in the filtrates, the iron coming away from the filter with the suspended matter, and the latter in consequence being granular, easily settled, and less liable to putrefaction. The septic tank and precipitation processes are useful in these cases due to the removal of a large proportion of the iron from solution before filtration.

21963. In dry weather what is the average amount of suspended matter in your sewage, and what are the highest and lowest figures, in parts per 100,000?—The average amount of suspended matter in our sewage for the years 1903–1904 is 60·1 parts per 100,000; the highest value obtained being 104 parts in September, 1903, and the lowest 33·5 parts per 100,000 in August, 1904.

21964. What is the physical character of these solids?—The suspended solids are more or less dark brown in colour and the bulk of them easily coalesce into flocculent masses and therefore are fairly easy to settle out. The remainder is very finely divided and only separates out very slowly.

21965. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—Yes, the average analysis for the years 1903 and 1904 was:

	Parts per 100,000.
Ammoniacal Nitrogen	1·84
Albuminoid Nitrogen	·602
Oxygen absorbed in four hours at 80° F.	10·8
Suspended Solids	60·1
Soluble Solids	102·2

I hand in a table showing the averages in winter and summer for 1903 and 1904.

	1903.		1904.	
	Winter—Jan., Feb., Nov., Dec.	Summer—June, July, Aug., Sept.	Winter—Jan., Feb., Nov., Dec.	Summer—June, July, Aug., Sept.
Ammoniacal nitrogen	1·91	1·99	1·78	1·87
Albuminoid nitrogen	·601	·584	·633	·619
Oxygen absorbed at 80 °F. in 4 hours	9 44	13·0	8·35	11·0
Suspended solids	55·3	77·5	63·9	49·8
Soluble solids	106·8	106·8	97·7	102·2

21966. Is it a "strong sewage," and, if so, what characterises its strength?—The sewage of Leeds is not strong with regard to organic impurity, but its treatment is complicated by the presence of one-third its volume of trade refuse.

21967. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—The strength of the sewage varies, but not to the same extent as when the bulk of the Trade refuse entered in flushes. Then, as I have before stated, the filtrates were affected by the varying amounts of the refuse in the sewage. That this refuse does affect the purification is shown in the treatment of Sunday and holiday sewages, which give much better results than normal. It is impossible at Leeds to compare different sewage strengths without referring to the amount of refuse present.

21968. Are there any chemical poisons in the sewage? If so, what are they, and to what extent do they occur?—Poisons do not occur to any great extent in the Leeds sewage. The chief being Arsenic Sulphide and a comparatively small amount of Thiocyanates.

21969. Is the sewage always alkaline?—Normally the sewage is neutral to litmus. The presence of an unusual proportion of trade refuse may make it slightly

acid or alkaline as the case may be, but not to a very appreciable extent.

21970. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours duration?—The following analytical data on the composition of storm water sewage was collected some time ago. (*a*) Average analysis of storm water sewage made during four periods of storm, each storm being over twenty hours duration. The average duration was twenty-eight and a half hours:—

Ammoniacal Nitrogen	·856
Albuminoid Nitrogen	·259
Oxygen absorbed in four hours at 80° F.	6·37
Suspended Solids	56·8
Soluble Solids	60·4

(*b*). Average of five storm water sewages, the average duration of each storm being thirteen and a quarter hours.

Ammoniacal Nitrogen	1·04
Albuminoid Nitrogen	·318
Oxygen absorbed in four hours at 80° F.	6·85
Suspended Solids	58·4
Soluble Solids	66·0

(*c*). Average of eight storm water sewages having an average duration for each storm of seven and a half hours.

Ammoniacal Nitrogen	1·26
Albuminoid Nitrogen	·435
Oxygen absorbed in four hours at 80° F.	9·87
Suspended Solids	67·2
Soluble Solids	73·4

Generally speaking the amount of suspended matter in storm sewages varies directly with the hourly rate of rainfall. A comparison of the above averages with those of the sewage shows that on the average storm waters contain practically the same amount of suspended matter as ordinary sewage. The amount of organic impurity present is however much smaller. The suspended solids in storm-waters caused by short heavy rain-storms are usually very high.

21971. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—I am not able to give analytical data of the liquid part of storm-waters produced either by settlement or filtration, but I can give an average analysis of a liquid produced by the precipitation of storm waters with one grain of sulphate of alumina and three grains of lime per gallon which may be of interest. The sewage remained in the tank for a period of four hours:—The analysis was:

Ammoniacal Nitrogen	1·14
Albuminoid Nitrogen	·160
Oxygen absorbed in four hours at 80° F.	2·18
Suspended Solids	9·0
Soluble Solids	59·4

Precipitated sewage, during the same months, precipitated with two grains sulphate of alumina and 6 grains of lime per gallon, and with an eight hours stay in the tank, gave an average result of:—

Ammoniacal Nitrogen	1·87
Albuminoid Nitrogen	·345
Oxgyen absorbed in four hours at 80° F.	4·38
Suspended Solids	9·7
Soluble Solids	101·0

21972. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely-increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking, by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—I am in general agreement with the provisions laid down by the Local Government Board for the treatment of storm waters especially that the storm water should undergo some method of treatment previous to entering a water course. As I have already shown storm waters, when deprived of most of their suspended matters, are not excessively polluted, consequently in the case of entry into non-drinking streams having a large volume in proportion to the sewage flow I think the case would be fully met by treating three volumes as in the ordinary way, the remaining three volumes being well settled or precipitated. At Leeds it has been found possible to treat the whole six volumes of storm water when well precipitated, upon a continuous filter having a depth of six feet and at ordinary times treating precipitated sewage at the rate of 100 gallons per square yard per twenty-four hours; the filtrate at such times being excellent in character, and being fairly free from suspended matter can be sent direct into a stream. The average analysis of this storm filtrate from July to December, 1904, was:—

Ammoniacal nitrogen	·357
Albuminoid nitrogen	·103
Oxygen absorbed in 4 hours at 80° F.	1·05
Suspended solids	7·1
Incubator test	before ·310 after ·320
Nitrogen as nitrate	1·39

Normal rate = 100 gallons per square yard. Storm water rate = 600 gallons per square yard.

Depth of filter 6 ft.

The occasional treatment of this large volume of liquid does not seem to affect the subsequent normal filtrates. Recent experiments point to the possibility of successfully treating all the six dilutions of storm waters after precipitation upon a 6 ft. continuous filter at the rate of 1,200 gallons per square yard. The average of the March, 1905, analysis is:—

Ammoniacal nitrogen	·514
Albuminoid nitrogen	·108
Oxygen absorbed in 4 hours at 80° F.	·860
Percentage of dissolved oxygen absorbed in 24 hours	27%
Nitric nitrogen	1·13
Suspended solids	8·1

Normal rate of filter 200 gallons per square yard. Storm water rate = 1,200 gallons.

Depth of filter = 6 ft.

This filtrate compares very favourably with the filtrate produced from a specially constructed storm-water filter filtering screened storm water at the rate of 500 gallons per square yard per 24 hours:—

Ammoniacal nitrogen	·460
Albuminoid nitrogen	·161
Oxygen absorbed in 4 hours at 80° F.	2·43
Suspended solids	14·4
Incubator test	before ·495 after ·581
Nitric nitrogen	·824

In the case of another filter 12 ft. deep and normally treating screened sewage at the rate of 200 gallons per square yard per day a similar series of experiments were instituted, the storm water being merely screened before being sent on to the filter. The rates of filtration varied from 600 to 1,200 gallons per square yard per 24 hours. The results are as follows: (*a*) The filtrate during storm

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times contained large quantities of suspended matter and was invariably putrescent, but after removing these suspended matters by straining through ashes a non-putrescent result was obtained. Naturally the higher rate of flow gave the worst results. The averages for 24 of these experiments were :—

	Unfiltered filtrate.	Filtered filtrate.
Ammoniacal Nitrogen - -	·558	·451
Albuminoid Nitrogen - -	·415	·089
Oxygen absorbed 4 hours at 80° F.	7·08	·921
Suspended solids - - -	59·2	—
Nitric nitrogen - - -	·027	·042
Absorption of dissolved oxygen in 24 hours - - -	100%	45%

(*b*) It was evident that these heavy doses of storm water have a deleterious effect upon the normal working of the filter, especially with the higher rate of flow. The filter, however, soon recovers itself, and with the lower rate of flow no difficulty should be experienced.

I have no experience in the treatment of storm water on contact beds with the exception of the special storm filters referred to. Briefly stated, my views are that storm waters up to three dilutions should undergo some efficient process before admission to a stream. That if nearly all solids are removed, then the six volumes of storm water may be treated on the ordinary plant, and if some solids are allowed to remain in the storm water, three volumes can be treated on the ordinary plant and the remainder by special storm filters, settlement, or precipitation. These remarks I intend to apply only to continuous filters and to comparatively weak sewages.

21973. Is your sewage settled, and, if so, how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be ? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids ?—The bulk of the sewage at Leeds is precipitated and settled continuously. Experimentally a small amount of sewage (about 45,000 gallons per day) is treated by continuous settlement without the addition of chemicals. The rate of flow through the tank was 4 hours from February to May and from August to September, 1904. The average analysis for these periods was :—

Ammoniacal nitrogen	1·60	parts per 100,000
Albuminoid nitrogen	·372	„ „ „
Oxygen absorbed in 4 hours at 80° F.	5·24	„ „ „
Soluble solids	91·7	„ „ „
Suspended solids	12·8	„ „ „

From June to July, 1904, and from October, 1904 to February, 1905, the rate of flow was 8 hours. The average of all analyses for this period was :—

Ammoniacal nitrogen	1·90	parts per 100,000
Albuminoid nitrogen	·413	„ „ „
Oxygen absorbed in 4 hours at 80° F.	5·84	„ „ „
Soluble solids	105·4	„ „ „
Suspended solids	11·7	„ „ „

21974. Have you data to show what proportion of the suspended matter in the Leeds sewage is settled in ½ hour, 1, 2, 3, 4, 5, 6, 12, and 24 hours, if the sewage is given quiescent settlement ?—Several experiments upon the quiescent settlement of sewage have been performed at Leeds in a tank having a capacity of 250,000 gallons. The following is a summary of the results obtained.

Date.	No. of Experiments.	Average amount of Suspended Solids (parts per 100,000).						
		in Sewage	¼ hr.	½ hr.	¾ hr.	1 hr.	1½ hrs.	2 hrs.
Mar. 10th & 11th, 1903 -	4	70·0	—	13·4	—	12·7	9·1	10·7
Mar. 16th & 17th, 1903 -	4	46·4	14·4	11·2	7·2	6·7	6·5	—

Experiments upon the quiescent settlement of limed sewage (3 grains per gallon) gave practically the same results.

21975. What time would be necessary for you to gain a good tank liquor containing, say, no more than six or eight parts of suspended solids per 100,000 from your sewage (without the addition of chemicals), by quiescent settlement, and by continuous flow settlement ?—Generally speaking two hours quiescent settlement will reduce the suspended solids to 8—10 parts per 100,000, and with continuous settlement about a twelve hours rate of flow would be advisable.

21975A. Do you prefer to use settlement tanks in series or in parallel ?—When a large volume of sewage is treated daily by continuous flow I prefer to use the tanks in parallel series of three to four. If all the tanks are in one series there is danger of the rate of flow becoming excessive and preventing the finer particles from settling out. In the case of quiescent settlement, I prefer the tanks in parallel.

21975B. In the case of continuous flow tanks, do you think there is any advantage in the employment of baffling boards or walls ?—Baffling boards or walls should be installed in several of the tanks to prevent a surface flow taking place.

21975C. How is the sludging done at your works and what is the character of the sludge ? Does any nuisance attend the operation ? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from your tanks ?—The tank to be cleaned out is isolated from the series by means of dam-boards and the liquid contents are run off by a special valve back to the pump-well. The sludge is then allowed to flow into a culvert—manual labour being required to push the sludge towards the valve—which gravitates to a sump. The sludge is pumped out of the latter into a small lagoon and allowed to stand at rest for twenty-four hours, during which period as much water is drained off as possible. From this lagoon the sludge gravitates into another lagoon of larger dimensions where a period of rest of two to three days is allowed and all water possible removed. The sludge which now contains from 80 to 85 per cent. water is run into the large lagoons, which when full are allowed to drain until the contents are spadeable, when they are removed and stored in heaps for the farmers to take. The sludge when freshly drawn from the tanks contains 90 to 92 per cent. water and runs in channels freely. Apart from the culvert no nuisance arises during these cleansing operations and certainly no smell from the culverts is appreciable in the open air. The sludge drying in the lagoons does give rise to smells, which however are not noticeable at a short distance from the lagoons. No serious complaints have been made.

21976. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge ?—With the foregoing method of dealing with sludge, I find it quite practicable to allow the road detritus to settle out in the tanks. All the heavy matter settles out around the inlet into the first tank, taking the form of a cone and thus allowing the ordinary sludging operations to be performed. This detritus is wheeled out of the tank after the ordinary sludge has been removed.

21977. You have had experience of the chemical precipitation of sewage ?—The method of treating the

bulk of the Leeds sewage is by precipitation with lime and this process has been in operation for many years. Experimentally other precipitants, either alone or in mixture have been used.

21978. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks? — Recent experiments at Leeds have shown that an effluent, produced by using eight grains of lime per gallon and two grains of sulphate of alumina and practically free from suspended matter, can be treated more easily than septic tank effluent or settled sewage upon trickling filters. This is due to the much smaller amount of suspended matter sent on to the filter. Thus in March, 1905, the results were:— *Mr. W. H. Harrison, M.Sc.* 11 May 1905

	Filtrate from filters. Treating settled sewage.		Filtrate from filter. Treating precipitated sewage.
	Unsettled.	Filtered.	
Ammoniacal N.	·420	·336	·500
Albuminoid N.	1·26	·041	·070
Nitric N.	1·60	2·15	1·52
Oxygen absorbed in four hours at 80° F.	1·39	·471	·581
Percentage of dissolved oxygen absorbed in twenty-four hours	·18	·5	·13
Suspended Solids	10·5	1·7	·8
Amount treated per cubic yard per twenty-four hours	61 galls.		100
Depth of filter	9ft. 6ins.		6ft.

The same filters treating the same liquids, but with the 6ft. bed, treating precipitated sewage at the rate of 49 gallons per cubic yard per day gave average results for 1904 of:—

	Filtrate from filter. Treating settled sewage.		Filtrate from filter. Treating precipitated sewage.
	Unsettled.	Filtered.	
Ammoniacal N.	·295	·253	·310
Albuminoid N.	·137	·070	·069
Nitric N.	1·27	1·42	1·81
Oxygen absorbed in four hours at 80° F.	1·64	·945	·69
Percentage of dissolved oxygen absorbed in twenty-four hours	32·8	15·7	10·3
Suspended Solids	12·9	6·4	2·1
Amount treated per cubic yard per day	61galls.		49
Depth of filter	9ft., 6ins.		6ft.

21979. Have you tried various chemicals. Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage?—Several precipitants have been tried upon Leeds sewage in order to obtain their relative values, but the question of cost has not been considered. The most effective precipitant was a mixture of ferric salts and lime closely followed in merit by aluminium sulphate and lime. These two precipitants were almost equally effective and were followed in order of merit by alum and lime, ferrous sulphate and lime, ferric salts, alum and ferrous sulphate. The last was practically valueless.

21980. What is the most effective way of adding chemicals?—Lime is best added in the form of lime water, but, as owing to the large volume of water required this is impracticable, recourse should be had to a weak milk of lime. The other chemicals where possible should be used in solution. To obtain the best results the amount of precipitant added should vary with the strength and volume of the sewage.

21981. What is the average analysis of the liquor from your precipitation tanks? What length of time does the sewage remain in the tanks?—The average for the years 1903 and 1904 is:—

Ammoniacal Nitrogen	1·68
Albuminoid Nitrogen	·306
Oxygen absorbed, 4 hours at 80° F.	4·61
Suspended Solids	11.1
Soluble Solids	98·9

The time the sewage remains in the tanks varies from about 3 hours to 6½ hours according to the rates at which the sewage is flowing through them, the average time being rather over four hours, only 3 grains of lime per gallon being used.

21982. Do you find it necessary to add further chemicals to the sludge before it can be dealt with?—No addition of chemicals to the sludge is necessary when it is dried in lagoons.

21983. What is the character of the suspended matter in the precipitation tank liquor?—The suspended matter in the effluent is very finely divided and settles out only very slowly. It is putrescent.

21984. What is the manurial value of the sludge obtained by the chemical precipitation of sewage at your works, and will farmers take it?—The manurial value of the sludge produced at these works is low as shown in the following analysis of the dried substance:—

	Per cent.
Loss on ignition	51·90
Sand and insoluble matter	16·97
Fe_2O_3 and Al_2O_3	14·12
CaO	12·11
S. as sulphate	·36
S present otherwise than sulphate	2·75
P_2O_5	1·16
The total nitrogen was	2·64

A certain proportion, about $\frac{1}{5}$ of the total production, is removed by the neighbouring farmers and rhubarb growers, who use it more as a rich earth than as a manure. There is no difficulty with the disposal of screenings, etc., as this is a good material for hot-beds. No doubt if greater facilities were offered to the farmers for its easy removal, more sludge could be disposed of. No charge is made.

21985. Does it contain any chemical poisons?—The sludge does not contain an appreciable amount of chemical poisons.

21986. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—No nuisance arises from the treatment of sewage in precipitation tanks; but arises from the mud drying in lagoons. No strong complaints have been made.

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21987. As regards septic tanks, how should they be shaped ?—Septic tanks should be rectangular in shape and from 6 to 8 ft. deep. It is preferable to have the flow across the short width of the tank so as to reduce the rate of flow of the liquid as much as possible. The outlet should draw off below the water level so as to retain floating matter within the tank.

21988. Should they be used in series or in parallel ?—Septic tanks are best used in parallel so as to reduce the rate of flow of the liquid to a minimum. Tanks in series do not appear to possess any decided advantage over tanks in parallel, as used at Leeds, with the exception that the first tank in a series accumulates the heavier solids and may be, therefore, oftener cleaned out. In an experiment where four tanks, of 500,000 gallons capacity each, formed a series, it was found that the rate of flow through the first tank prevented septic action occurring, and as there was consequently no disturbance of the sludge, the latter accumulated so rapidly in the first tank that in a few months' time it was full of a very solid sludge.

21989. Should the septic tank be closed in, and, if so what advantages does a closed tank possess over an open one ?—Closed septic tanks do not possess any advantage over open tanks unless from the point of view of nuisance arising in densely populated districts, but even then the danger is only minimised. The effluents from both tanks are almost identical in composition. The averages of all analyses of effluents from Nos. 1, 2, and 3 open septic tanks and also effluents from covered septic tank from October 1899 to May 1904 were—

	Open Tank.	Closed Tank.
Ammoniacal Nitrogen - -	1·85	1·87
Albuminoid Nitrogen - -	·443	·418
Oxygen absorbed in 4 hours at 80° F. - - - -	6·10	5·48
Soluble Solids - - - -	89·4	88·1
Suspended S lids - - -	19·4	16·0

It is also found that the value of the roof in conserving the heat of the sewage is very small, for during cold weather the average loss in temperature in the open tanks was 1·6° F. and in the closed tanks ·8° F. The heating value of the collected gases is not great and their accumulation within the tank constitutes a serious source of danger. Briefly, I do not find any decided advantage arising from the use of covered tanks sufficient to justify the expenditure.

21990. What do you consider the best arrangement for the "feed" and "draw-off ?"—I do not attach great importance to the question of the best method of feeding the tank, for both the methods, feeding below and on the surface level, answer equally well. The outflow should, however, take place from below the surface.

21991. At what rate is sewage, as a matter of custom, passed through your septic tanks ?—At Leeds a 24 hour rate of flow has been adopted as the normal flow.

21992. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous ? Why do you consider one rate more advantageous than another ? Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with ?—The 24 hour rate of flow has been adopted as giving the best results, from the point of view of the amount of suspended matter in the effluent, with a minimum length of time within the tanks. It was found that even a 72 hour flow gave very little better results than a 24 hour flow, but that as the rate of flow was increased above the normal a larger proportion of suspended matter tended to come away from the tanks. I give an average of analyses showing the effect of different rates of flow through open septic tanks.

	12 hr. flow.	24 hr. flow.	48 hr. flow.
Ammoniacal N. -	1·65	1·76	1·82
Albuminoid N. -	·590	·409	·443
Oxygen absorbed 4 hrs. 80° F. - -	8·15	6·24	6·10
Soluble solids - -	97·7	95·3	96·7
Suspended solids -	28·0	16·4	15·5

These observations were made in 1899 and 1900 and during 1901 and 1902 they were extended to a comparison of a 24 hour and 72 hour flow, viz. :—

	24 hr.	72 hr.
Ammoniacal N. - - - -	2·17	2·10
Albuminiod N. - - - -	·453	·403
Oxygen absorbed 4 hrs. 80° F. -	6.45	5.12
Soluble solids - - -	90·1	91·4
Suspended solids - -	21·7	14·1

I believe that the rate of flow should depend upon the character of the suspended solids in the sewage dealt with.

21993. Is it possible to "over-septicise" a sewage ?—I have never found it possible to over-septicise sewage even with the 72 hour flow. In that case when the effluent was applied in a normal manner to filters, normal results were obtained.

21994. What is the amount of digestion in your septic tanks and how do you calculate this ? How far do you find that the digestion is affected by the atmospheric temperature ?—The average amount of digestion obtained in the Leeds septic tanks is about 30 per cent. of the sewage suspended solids. As an example I give the method of calculating the digestion from data derived from Nos. 1, 2 and 3 open septic tanks from 1903 to 1904 :—No. 1 tank contained 667 tons of sludge containing 14·2 per cent. solids = 94·7 tons of dry solids ; No. 2 tank contained 818 tons of sludge containing 14·2 per cent. solids = 116·1 tons of dry solid ; No. 3 tank contained 547 tons of sludge containing 16·2 per cent. solid = 88·6 tons dry solid *i.e.* from all the tanks combined there was obtained a total of 299·4 tons dry solids from which, deducting 15·3 tons of sludge use for inoculation purposes, and adding 1·49 tons for the dried scum removed from the tanks, is left 285·59 tons of undigested solids in the tank. The tanks were working 627 days exclusive of stoppages and in this period treated a total of 470,300,000 gallons of sewage containing an average of 33·2 grains of suspended matter per gallon. This gives a grand total of 995·9 tons of solids entering the tanks with the sewage. $\left(\frac{470,300,000 \times 33{\cdot}2}{7000 \times 2240}\right)$ The effluent carried away an average of 12.7 grains of suspended matter. Thus 381 tons of solids were carried away in the effluent. The undigested solids = solids present in the tank as sludge + solids carried away in the effluent = 381 + 285·59 = 666·59 tons *i.e.* 329·31 tons of solids have been digested giving a digestion of 33·0 per cent. I have no data bearing directly upon the effect of the atmospheric temperature upon the digestion : judging from the evolution of gas it must be considerable *e.g.* in a certain area of a small experimental tank, during August 1901, 37 litres of gas were daily collected, but in November 1901, only 13 litres were collected.

21995. Do you think a certain amount of sludge should be removed periodically from septic tanks or do you prefer to work them for a considerable period without cleaning and then remove all the sludge ?—A certain amount of sludge ought to be removed at periodic intervals in order to facilitate the treatment and disposal of the sludge. There is also a tendency for the sludge in the tanks to become consolidated, if left too long undisturbed, causing difficulty in the withdrawal of the sludge from the tank.

21996. How often would you clean out the tanks ?—The tanks at Leeds are generally cleaned out every two years but it would be preferable to do this say every eighteen months. If the tank is left uncleaned for too long a period the suspended solids in the effluent become excessive.

21997. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.* as the time approaches for removing sludge from the tanks ?—The

amount of suspended solids in the effluent, apart from occasional flushes of solids, does undoubtedly tend to increase as the sludge accumulates within the tank.

21998. What amounts of suspended solids are contained in your septic tank liquor at the commencement of the period of working the tank, just after the tank has been cleaned out, and at the end of period when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount ?—From January to June 1903 with a perfectly clean tank the suspended solids averaged 12·2 parts per 100,000 and from July to December 1904 the effluent from this tank averaged 24·1 parts.

21999. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way, as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank ?—The closed septic tank at Leeds is operated upon the principle of a fluctuating water level, and in no way has this affected the character of the effluent. Again, at one time in order to obtain a large bulk of liquid in a short period of time it was the practice to lower the water level of the open septic tanks from nine inches to one foot. This procedure had no effect the scum and suspended solids remaining normal.

22000. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor ? —I have not found that septic tank effluent is more easily treated upon filters than settled or precipitated sewage. Two single contact beds, one treating septic tank effluent and the other precipitated sewage, gave the following average results :—

	Filtrate from Bed treating Septic Effluent.	Filtrate from Bed treating Lime Precipitated Sewage.
Ammoniacal N.	1·46	1·47
Albuminoid N.	·193	·193
Oxygen absorbed 4 hrs., 80° F.	1·51	1·45
Nitric nitrogen	·067	·077
Soluble solids	92·4	92·0
Suspended solids	9·5	6·4

These figures are the averages of all analyses extending over a period of two years. The septic tank effluent and the lime precipitation effluent contained approximately the same amount of suspended solids Septic tank effluent and settled sewage containing approximately the same amount of suspended solids gave the following average results when treated upon the same continuous filter. The septic tank effluent was used in 1903 and the settled sewage in 1904, the bed being washed out between the experiments :—

	Filtrate from Bed treating Septic Tank Effluent.		Filtrate from Bed treating Settled Sewage.	
	Unfiltered Effluent.	Filtered Effluent.	Unfiltered Effluent.	Filtered Effluent.
Ammoniacal N.	·408	·374	·295	·253
Albuminoid N.	·142	·076	·137	·070
Nitric nitrogen	·913	1·06	1·27	1·42
Oxygen absorbed 4 hrs., 80°F.	1·90	·734	1·61	·945
Dissolved oxygen taken up in 24 hrs.	35%	24%	32%	15%
Incubator test before	·59	·29	·58	·34
Incubator test after	·61	·32	·54	·31
Suspended solids	11·2	3·0	12·9	6·4

I am of opinion that septic tank effluent and precipitated or settled sewage, provided that the amount of suspended solids is approximately equal, give practically identical results when subjected to similar methods of treatment.

22001. Do you find any nuisance from the treatment of sewage in septic tanks ? Have any complaints been made ?—Very little, if any, nuisance arises from the open septic tanks at Leeds. This is probably due to the presence of iron in the sewage, which, under septic action, forms sulphides of iron in the tank and consequently the production of evil smelling organo-sulphur compounds is prevented to the extent of the production of iron sulphides.

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22002. Is a scum necessary or desirable in septic tanks ?—One of the difficulties experienced at Leeds has been caused by heavy flushes of suspended matter from the tanks, whether open or closed. This has been traced to the breaking up of the scum and occurs chiefly during wet weather, and for the past two years it has been the custom at Leeds to keep the surface of the tanks free from scum. This has prevented, to a great extent the flushes of suspended matter from the tanks, and the absence of scum has not interfered in any way with the action of the septic tanks.

22003. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered ? If so, what do you consider a practicable limit to get down to ?—It is comparatively easy to purify the liquid part of sewage, but the solids are much more difficult to oxidize to a stable form. The difficulty of treating any liquid effectively is proportionate to the amount of suspended matter present, hence the latter should be removed as far as practicable before filtration. With septic tanks, even with a seventy-two hours' flow, it is impossible at Leeds to reduce the suspended solids below an average of fourteen parts per 100,000. Precipitated sewage containing about 4·5–6 0 parts of suspended matter I find is very easily treated on filters, especially those of the continuous type.

22004. How do you consider that the removal of suspended solids can best be effected ?—In order to reduce the suspended solids as far as possible, precipitation with an efficient settlement area should be adopted. In some cases sedimentation without chemicals would answer.

22005. As regards contact beds, do you find that within certain limits the depth may vary without affecting the efficiency of the beds ? If so, what limits do you think are permissible ?—At Leeds, contact beds, varying in depth from three to six feet have at one time or another been used, and within these limits the primary and secondary beds having a depth of six feet gave somewhat better results than those of less depth. This difference I do not attach importance to, as differences in material, and the grading thereof, and the methods of working the beds might account for it.

22006. What do you consider the most convenient size for a contact bed ?—For large volumes of sewage I consider the most convenient size for a contact bed to be half-acre area.

22007. What do you find to be the best filtering materials ? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed ?—I have only had experience of destructor clinker and coke of various qualities, and of these I prefer hard furnace coke.

22008. What size should the filtering material be, and should it be graded in the beds ?—The size of the material used in contact beds should be as small as is conformable with other conditions, *e.g.*, if the liquid to be treated contains little or no suspended matter the material may be clinkers or coke-breeze with only the dust taken out, but otherwise the material for the primary bed should have a diameter of one inch or over, the secondary bed being made of much smaller material. Apart from covering the drainage with coarse material, and in certain cases the use of a very fine surface layer, I see no advantage in grading the bed material.

22009. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds ?—Sewage, screened or grit settled, I consider, should not be applied to contact beds, owing to the very rapid loss of capacity which occurs. To minimise this loss of capacity it should be subjected to treatment having the primary object of reducing the amount of solids sent on to the bed ; incidentally better nitrated filtrates are produced.

22010. What periods of filling, standing full, emptying and standing empty do you consider best in practical working for primary beds and for secondary beds ?—The method of working the beds at Leeds is :—one hour to fill, two hours standing full, one hour to empty, and

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four hours standing empty. This cycle is repeated every eight hours, both for primary and secondary bed. In order not to overwork certain filters it has been the practice to follow the above procedure for two eight-hour shifts and to rest the beds completely for the third shift. Longer periods of rest have been tried at Leeds. Thus No. 1 and 2 beds, from February 20th to March 18th. 1899, received two fillings per day with two hours contact and rested altogether on Sundays. Under these conditions a purification of 87 per cent. on the Alb. N. test was obtained. From March 21st to May 7th, 1899 they were worked in the same way, but were allowed to rest on Wednesdays and Sundays and gave a purification of 89 per cent. From May 7th to July 5th, 1899, they were allowed to rest alternate days, and gave a purification of 92 per cent. From July 5th to October 4 h, 1899, with one filling per day and two hours contact they gave a purification of 90 per cent. These facts point to an increased purification being obtained with increased periods of rest. Very little advantage, if any, is gained by increasing the hours of contact from two to four hours.

22011. How should contact beds be filled and emptied ?—Contact beds should be filled as quickly as possible, without disturbing the surface material and it is essential that the liquid should be distributed over the whole surface as evenly as possible. This has been attained after numerous experiments with movable troughs in various forms, by cutting grips in the surface material about three feet apart and connected together at intervals by cross channels. These grips are far more effective than troughs, etc., and any sludge which accumulates within them is easily removed. In emptying, the best method is to allow the liquid to flow away from the bed at an even rate, controlling the flow by means of valves.

22012. What are your views as regards automatic gear for filling and emptying contact beds ?—The only gear used at Leeds for automatically filling and discharging contact beds is the one supplied by the Exeter Septic Tank Syndicate. This is very complicated, but on the whole works very well. Owing, however, to the danger of the smaller tubular parts clogging it is necessary to give constant supervision. This apparatus regulates very well the time the liquid is in contact with the bed material, but it would not be an easy matter to readily alter this length of period if necessary. The chief objection to this apparatus lies in its inelasticity, for the daily routine having been fixed it would take some considerable time to alter the relationship of the various parts to suit another system of working. This gear does not take into account the fluctuations in the flow due to increases in volume, chiefly because of the fact that a bed is not filled until the one before it in the cycle has had its full period of rest and is emptying.

22013. What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed in twenty-four hours ?—The amount of tank liquor which a primary bed can treat per cubic yard of filtering material depends upon loss of capacity which has taken place since its construction. A primary contact bed when new and receiving three fillings per day of crude sewage, at Leeds, treated about 200 gallons per cubic yard per day, but at the end of two years would, at this rate of working, only treat about sixty-six gallons per cubic yard per day. Analytically the results were satisfactory throughout the whole period. Again, another bed, receiving two fillings per day of septic tank effluent and resting one week in every four, when new, treated an average of about 120 gallons per cubic yard per day ; but in March 1905, four years later, could only treat an average of about fifty-four gallons per cubic yard for twenty-four hours. This bed has treated on the average during the past two years about sixty-five gallons per cubic yard per day with really excellent results.

22014. What amount of liquid from a primary bed can in practice be properly treated on each cubic yard of filtering material of a secondary bed ?—It has been the practice at Leeds to treat liquid on secondary beds at the same rate per cubic yard as on the corresponding primary beds.

22015. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent ?—I have never been able to produce a satisfactory filtrate with a single contact bed. In the great majority of cases the filtrate has been putrescent and unsightly.

22016. At what rate or rates do primary and secondary contact beds lose their water-holding capacity, and to what causes is the loss of capacity due ?—The rate at which primary contact beds lose their capacity varies directly with the amount of suspended solids in the liquid treated, lessens with increased periods of rest and is greater in winter than in summer. Secondary beds as a rule retain a large percentage of their initial capacity.

The rate is in direct proportion to the suspended solids in the liquid treated.—A primary contact bed from October, 1897, to October, 1899, treated about 56,000,000 gallons of more or less crude sewage and in this period lost 56,500 gallons of the initial water capacity, *i.e.*, every 1,000,000 gallons of the sewage caused an average loss in capacity of about 1,000 gallons.

Another primary bed from July, 1901, to January, 1904, treated 106,000,000 gallons of septic tank effluent and lost 46,400 gallons of its original water capacity, *i.e.*, every 1,000,000 gallons of septic tank effluent treated produced an average loss in capacity of 437 gallons.

Again on the same primary bed with sewage which had been settled for one hour the rate of loss of capacity was 690 gallons per 1,000,000 treated ; with sewage which had been settled half an hour the rate was 820 gallons, and with sewage which had been settled a quarter of an hour the rate was 1,580 gallons. Screened sewage under the same working conditions reduced the capacity at the rate of 2,060 gallons.

The rate is in the inverse ratio to the amount of rest given to the beds.—A primary bed treating screened sewage at three fillings per day reduced the capacity at the rate of 1,750 gallons per 1,000,000 treated, and at two fillings per day at the rate of 680 gallons. This experiment was carried out in the spring of 1898.

In the early part of 1899 partially settled sewage at three fillings per day reduced the capacity at the rate of 2,000 gallons per 1,000,000 gallons treated. The same liquid at three fillings per day, but with the bed resting on Wednesdays and Sundays reduced the capacity at the rate of 1,300 gallons, and with three fillings per day but the beds resting on alternate days there was an increase in capacity at the rate of 1,500 gallons.

The rate is greater in winter than in summer.—I have taken as an example a bed treating septic tank effluent since 1901 under uniform conditions.

Year.	Rate of loss of capacity per million gallons, treated in	
	Winter (Dec. Jan. Feb.)	Summer (June July August)
1901	680	—
1902	280	160
1903	450	Nil
1904	750	440
Average	540	200

In order to show the way in which loss of capacity takes place I give the following capacity tests of a primary bed working under uniform conditions, the capacity of the empty bed being taken as 100, the actual figure being 178,000 gallons :—

Date.	Capacity with the 100 unit.	Actual galls.
1901 July 16 - -	48·8	86,900
September 27 -	44·4	79,100
November 22 -	42·8	76,200
December 20 -	44·4	79,100
1902 February 14 -	41·2	73,300
April 11 - -	39·5	70,300
June 6 - -	38·7	68,900
August 29 - -	37·9	67,400
October 24 - -	37·0	65,900
December 19 -	37·0	65,900

Date.	Capacity with the 100 unit.	Actual galls.
1903 February 13	35·9	64,000
April 9	34·8	62,000
June 5	33·7	60,000
August 1	33·7	60,000
October 23	33·3	59,400
December 18	31·6	56,200
1904 February 1	29·9	53,200
April 8	29·1	51,800
June 3	28·6	50,900
August 26	27·1	48,100
October 21	25·7	45,700
December 16	22·7	40,500
1905 February 10	20·5	36,600

This bed was receiving two fillings per day of septic tank effluent and was allowed to rest one week in every four, so that in no sense was it overworked. The analytical figures for septic tank effluent have already been given in answer to a previous question (21989). The bed received about forty-one fillings per month on the average.

Loss of capacity is due to the following causes :—

(1.) The passage of undigestible matters into the body of the filter.

(2.) The breaking down of the bed material.

(3.) The consolidation or packing together of the bed material.

(4.) The formation of a form of organic earthy matter akin to humus within the body of the filter.

(5.) The large amount of water retained in spongy deposit around the bed material.

22017. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard ?—The bed material may be readily washed and this I have done to the extent of 1,020 cubic yards by hand labour using screens and a heavy flow of water at a cost of 2s. 5d. per cubic yard. With the use of mechanical apparatus, the cost should be very considerably reduced. Washing is much more effective than turning over the bed material in regaining capacity. The latter method answers for the first time, but afterwards makes very little difference in the capacity.

22018. What is the average analysis of your single contact effluent ?—An average analysis of the filtrate from a single contact bed treating precipitated sewage gives : —

Ammoniacal N.	1·47
Albuminoid N.	·193
Nitric nitrogen	·077
Oxygen absorbed four hours at 80 °F.	1·45
Suspended Solids	6·4

An average of analyses of filtrate from a single contact bed treating open septic tank effluent gives :—

Ammoniacal N.	1·46
Albuminoid N.	·193
Nitric N.	·067
Oxygen absorbed four hours 80 °F.	1·51
Suspended Solids	9·5

An average analysis of filtrate from single contact beds constructed by the Septic Tank Syndicate and treating effluents from closed septic tank (October, 1899, to May, 1904) gives :

Ammoniacal N.	·849
Albuminoid N.	·161
Nitric N.	·695
Oxygen absorbed 4 hours 80° F.	1·09
Percentage of dissolved oxygen absorbed (1903 to 1904)	44
Suspended Solids	4·85

An average analysis of filtrate from double contact beds treating more or less screened sewage (November, 1898 to October, 1899) gave :

Ammoniacal N.	·374
Albuminoid N.	·095
Nitric N.	·560
Oxygen absorbed	·714
Suspended solids	2·71

An average analysis of filtrate from double contact beds treating septic tank effluent (1903 and 1904) gave :

Ammoniacal N.	·186
Albuminoid N.	·035
Nitric N.	2·07
Percentage of dissolved oxygen absorbed	16
Oxygen absorbed 4 hours 80° F.	·520
Suspended solids	heavy trace

22019. Do you find any chemical poisons in you final effluent ?—No chemical poisons are present in the effluents.

22020. What is the average amount of suspended matter in the primary bed effluent and in the secondary bed effluent ? Does most of this suspended matter come out with the first flush or not ?—The amount of suspended matter in the primary and secondary bed effluents varies with the amount of solids in the liquid treated. With more or less crude sewage, the primary bed gives an average of 16·3 and the secondary bed 2·71 parts of suspended matter per 100,000. With septic tank effluent the primary bed filtrates give an average of 10·4 parts per 100,000 and the secondary bed filtrates only a heavy trace. The greater portion of these suspended solids are found in the first flushes.

22021. Have you made any experiments which throw light upon the action of contact beds when full and when resting, or upon the conditions of aeration of contact beds ? —From a comparison of the results obtained from contact beds working under various conditions and treating liquids of various compositions, I hold the opinion that the action of these beds may be divided into two distinct headings, viz., (1) the oxidation of the solids and (2) the oxidation of the liquid impurity. When a bed is filled the solids during the period of resting full, settle out on the bed material, and the greater proportion of them are retained so as to gradually pass through the body of the filter during subsequent operations. These solids, and also any solids removed from solution, when the bed is resting empty are oxidised with the production of nitrates, etc., which in the following filling are dissipated throughout the body of the liquid. The liquid impurities are then oxidised, when the bed is full : (1) at the expense of any dissolved oxygen and (2) at the expense of the dissolved nitrates, etc., formed by the oxidation of the solids when the bed is resting empty. These liquid impurities are very easily oxidized and in many cases if it were practicable to remove the suspended solids from the primary bed filtrate the clear liquid would fall below the provisional standards. This heory accounts for the following facts :—(1) the effluent from a primary contact bed is devoid of dissolved oxygen, but contains more or less nitrates according to the length of time the bed rests empty. The soluble solids in the liquid in the first bed are very unstable and readily oxidised, hence the dissolved oxygen is soon used up, while the nitrates which then become available are destroyed in proportion to the length of time the bed stands full. Thus a single contact bed at Leeds receiving two hours contact and four hours rest gives a filtrate with no dissolved oxygen and only ·067 parts of nitric nitrogen, whilst a single contact bed receiving the same type of liquid, but only having one and a quarter hours contact and about twelve hours rest gives a filtrate containing no dissolved oxygen and ·695 parts of nitric nitrogen. This latter filtrate when saturated with air absorbed practically all the dissolved oxygen, while the former, containing less unoxidized dissolved impurity, absorbed less of this dissolved oxygen. (2) As the liquid impurities are oxidized when the bed is full at the expense of the dissolved oxygen and the nitrates present in the liquid it follows that a period of contact longer than is necessary to utilize this supply of oxygen is useless. This is borne out by experiment at Leeds ; for a four hours contact is no better than a two hours contact. (3) The filtrate from a secondary bed contains dissolved oxygen showing that the oxidation taking place in the first bed has been effective, and all the dissolved oxygen introduced into the liquid during its passage from the primary into the secondary bed has not been needed for further oxidation in the latter bed, the over-plus appearing in the final filtrate as " dissolved oxygen." It also follows that most of the nitrate formed in the secondary bed during its period of rest appear in the final filtrate. Hence the better oxidized a first bed effluent is the greater amount of dissolved oxygen and nitrate is found in the filtrate

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from the second bed. This is borne out by experiment. The actual course of the oxidation of the two kinds of organic impurity is not so definitely divided as is given in the foregoing brief account, for part of the solids are oxidised when the bed is full and part of the retained liquid when the bed is empty. This is shown by the fact that the more solids a liquid contains the worse the quality of the filtrate. In this connection it must be remembered that even when the bed is resting empty the amount of air available is limited to about the capacity of the bed; hence with liquids containing large amounts of suspended matter there is always an over-plus left unoxidized during these periods of rest which use up the available oxygen and nitrate of the next filling, causing a surplus of unoxidized soluble solids in the filtrate, and necessarily deteriorting the quality of the secondary filtrate. Summarizing these conclusions the period of aeration should be as long as is practicable, the time of contact in primary beds should only be long enough to use up the available oxygen and nitrates, and the liquid to be treated should contain as few solids as possible.

22022. How can the capacity of contact beds be best maintained?—In order to maintain the capacity of contact beds at as high a figure as possible no solids should be sent on to the filter. Where this is impracticable good results have been obtained at Leeds by the use of septic tank effluent upon a primary bed constructed of fine material (clinker) of three-eighths to five-eighths inches diameter and covered with a surface layer of very fine coke breeze to a depth of six inches. By this means a larger proportion of the solids in the septic tank effluent are retained in the feeding grips and when dry are easily removed. Such a primary bed has been in use at Leeds for nearly four years, but notwithstanding these precautions the water capacity has been reduced during that period from 86,000 gallons to 36,000 gallons. The experience at Leeds has been that the material of contact beds will sooner or later have to be washed or renewed.

22023. As regards continuous or percolating filters, what do you find are the best filtering materials, and what size should the material be?—I find coke to be the best material as clinker breaks down very readily. Broken bricks or any material which is not liable to disintegration answers better than coke. The material should be of such a size that the solids can gradually pass through the filter and appear in the filtrate. Material of not less than three inches diameter is a useful size.

22024. What depth should a percolating bed be to obtain a good effluent?—The depth of the filter should vary according to the amount of solid in the liquid treated. Thus with screened sewage containing an average of about fifty seven parts of suspended matter, a bed from ten to twelve feet deep is needed. With septic tank effluent or settled sewage containing about fifteen to seventeen parts of suspended matter a bed from eight to ten feet is needed, and with a liquid containing only a small proportion of suspended matter, such as well precipitated sewage, a bed from five to six feet deep will answer.

22025. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?—It is desirable to remove as much suspended matter as possible from the sewage (1) owing to the ease and rapidity with which a clarified liquid can be treated, and (2) the absence of a large amount of suspended matter in the filtrate, thus obviating the necessity for any after treatment of the filtrate to remove these solids.

22026. How should percolating filters be fed?—Liquids should be distributed over percolating filters in such a way that each unit of surface receives the same volume of liquid in a given time.

22027. Should the feed be intermittent or continuous?—The feed should, if possible, be continuous as any intermittency tends to produce a filtrate fluctuating in quality. This applies more especially to filters constructed of coarse material.

22028. What is the best form of distribution? What, in your opinion, are the conditions which have to be fulfilled by a perfect distributor, having regard not merely to the distribution of the liquid itself, but also to the purification of the liquid and the life of the bed?—The best form of distribution is by means of sprinklers. A sprinkler should be able to deliver liquid in a continuous stream on to the surface within wide limits of volume per unit area; it should rotate smoothly and easily and not be affected by wind pressure to any great extent; the exit holes on the rotating arms should be large enough to pass particles of growth, and it should be possible, with great ease, to clean the interior of the arms. The bearings of a sprinkler should be outside the flow of sewage and no alternating gear should be provided unless absolutely necessary. In that case, when the sewage flow is small, the arms come to rest during the period in which the sewage is accumulating. When the sewage is released a large volume passes through a very small portion of the filter, and this continues until the arms gain momentum. Tipping troughs, fixed troughs, and tray methods of distribution are all open to the objection that with rates of flow such as 200 gallons per square yard they are very liable to freeze in winter.

22029. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—The rate of flow on to a filter can be increased in storm-times without causing any detriment to the filter. In the case of liquids free from suspended matters being treated, the rate of flow can be increased from 200 to 1,200 gallons per square yard with impunity.

22030. Is there any practical advantage in artificially heating the liquid which is being treated on percolating filters?—There is no practical utility in heating the liquid sent on to precolating filters. Filters unheated in any respect give at Leeds filtrates which in winter are non-putrescent and generally well below the provisional standard.

22031. Have you had any experience to show whether open sides are an advantage to a percolating filter?—A comparison of the filtrates from various types of filters shows that side æration is not necessary. A filter at Leeds constructed without side æration gave fully ærated and well-oxidized filtrates. In this case the bottom of the filter was well ærated.

22032. Have you made any study of the conditions of æration of percolating filters, and is it desirable that the bottom of the filter should be raised from the ground?—A study of the conditions of æration has shown that to maintain the efficiency of a filter it is essential that there must be a free admission of air to the base of the filter and that the top surface must be kept free from growth so that no ponding occurs. It is, therefore, desirable that the base of the filter should be above ground level.

22033. What do you consider the most convenient superficial area for a percolating filter?—For large volumes of sewage, filters having a diameter of from 100 to 150 feet would seem to be desirable.

22034. Do percolating beds, in your experience, choke? If so, have you been able to measure the rate of choking, and how do you suggest that this choking can be removed and at what cost?—Filters constructed with material which is liable to disintegrate or which is too fine, do readily choke. Thus a filter constructed of clinker having a diameter of three-eighths to five-eighths inch became useless at the end of two years, whilst a filter constructed of coke having a diameter of two and a half inches and upwards is still giving satisfactory results after a working period of six years. Both of these filters were treating septic tank effluent. A filter constructed of slabs of clinker each about one foot across and packed vertically by hand became useless in less than two years owing to the disintegration which had taken place. The only effective way to prevent choking is to use a hard material, which does not easily wear, and in pieces over three inches diameter. In this case, any solids which accumulate may be largely washed out by means of large volumes of water. The heavy flow through such a filter when storm waters are treated also tends to keep it free.

22035. Of what nature are the suspended solids in the filter effluent?—How much is organic matter, and are they putrescible apart from the liquid portion of the

effluent ?—An analysis of the chief constituents of the sludge deposited from a continuous filter effluent is :—

	per cent.
Loss on ignition	40·4
Sand and insoluble matter	18·9
Oxides of iron and alumina	31·3

This sludge is usually non-putrescent.

22036. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter, and to what minimum figure do you think such settlement or other final treatment can be carried as a *practical* measure ?—Solids in these filtrates are readily settled out as they are heavy and granular in appearance, but a better and more effective method is by mechanical filtration. The filters are constructed of fine furnace ashes and have a depth of six inches, with side walls rising about two feet above the surface of the ashes, so that the liquid to be filtered can pond up to that depth. The whole is underdrained by means of agricultural tiles. In practice the filter effluent is run on to the surface at the rate of 400 gallons per square yard, and percolating through the material becomes freed from suspended solids. Such a filter will continue to treat a filtrate containing about eleven parts per 100,000 of solids for a period of about one month before it becomes necessary to stop the flow on to it. The filtered solids soon drain dry and splitting up into small cubes are easily scraped from the surface, the filter being then ready for use again. In practice it is possible to produce a result containing from four to five parts per 100,000 of solids.

22037. Do you find that the suspended solids in your filter effluent vary very much in amount from time to time, and, if so, can you explain the causes of such variation ?—The solids in the filter effluent vary very greatly in amount, the largest quantity appearing in spring and autumn. Generally speaking there are more solids present during the warmer months of the year, and the fluctuations are more pronounced with a comparatively new filter. It is usually found that after one of these periods of flushing out of solids that the suspended matter present in the filtrate shows a diminution in quantity. The average amounts of suspended matter per month in the filtrate from a bed treating septic tank effluent were :—

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Month.	1902	1903
January	11·1	8·9
February	19·8	1·4
March	19·8	9·5
April	10·4	8·7
May	2·7	10·4
June	1·7	16·4
July	13·0	5·0
August	10·2	12·8
September	6·0	10·4
October	7·8	15·2
November	8·2	12·5
December	4·1	12·2

These flushes would appear to coincide with the activity of the higher forms of life within the filter.

22038. What was the cost of your percolating bed installation per acre, and how much liquid do you treat per acre per twenty-four hours, at ordinary times and in storm times ? Please give the depth of the filter and an average analysis of the liquid which you put on, and an average analysis of the effluent when working at the ordinary rate and when working at a greater rate in storm times ?—As all the various filters at Leeds have only been experimental no reliable figures can be given, but the cost, calculated per acre, for continuous filters from nine to ten feet deep has been about £9,000 to £13,000 per acre, according to the manner of construction. In ordinary times the usual amount treated is 200 gallons per square yard per twenty-four hours, rising in times of storm to 1,200 gallons per square yard. The following are the average analyses :—

I. Filter treating Septic Tank Effluent and having a depth of 9 ft. 6 in. of Bed Material (1903).

	Septic Tank Effluent.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·05	·403	·374
Albuminoid N.	·363	·142	·076
Nitric N.	—	·993	1·06
Oxygen absorbed 4 hrs., 80 °F.	5·96	1·09	·734
Incubator Test before	—	·59	·29
Incubator Test after	—	·61	·32
Dissolved Oxygen absorbed in 24 hours	—	35 per cent.	24 per cent.
Suspended Solids	15·9	11·2	3 0

No storm waters were treated on this filter.

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II. Filter treating Settled Sewage and having a depth of 9 ft. 6 in. (1904).

	Settled Sewage.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·73	·295	·253
Albuminoid N.	·388	·137	·070
Nitric N.	—	1·27	1·428
Oxygen absorbed 4 hours, 80° F.	5·50	1·64	·945
Incubator Test before	—	·581	·349
Incubator Test after		·545	·319
Dissolved Oxygen taken up in 24 hours	—	32·8 per cent.	15·7 per cent.
Suspended Solids	12·2	12·9	6·4

III. (*a*) Filter 12 Ft. Deep and Treating Crude Sewage (Screened) 1902 and 1903.

	Screened Sewage	Filter Effluent.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	2·30	·721	·516
Albuminoid N.	·769	·277	·104
Nitric N.	—	·350	·591
Oxygen absorbed 4 hours 80° F.	10·2	3·08	·934
Incubator Test before	—	1·28	·39
Incubator Test after	—	2·25	·46
Dissolved Oxygen absorbed in 24 hours	—	71%	39%
Suspended Solids	53·2	21·0	3·5

(*b*) Same Filter when treating Storm-waters at the rate of 600 gallons per square yard.

	Storm Water.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·10	·422	·401
Albuminoid N.	·337	.270	·076
Nitric N.	—	·041	·070
Oxygen absorbed 4 hours 80° F.	7·55	4·12	·835
Dissolved Oxygen absorbed in 24 hours	—	100%	37·5%
Suspended Solids	68·7	68·1	—

(*c*) Same Filter when treating Storm-waters at the rate of 1,200 gallons per square yard.

	Storm Water.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·36	·700	·501
Albuminoid N.	·386	·561	·109
Nitric N.	—	·014	·015
Oxygen absorbed 4 hours 80° F.	9·01	10·0	1·00
Dissolved Oxygen absorbed in 24 hours	—	100%	54·1%
Suspended Solids	61·5	64.0	—

IV. (*a*) Filter 6 feet deep and treating precipitated sewage at the rate of 100 gallons per square yard per 24 hours (1904) :—

	Precipitated Sewage.	Bed Filtrate.
Ammoniacal N	2·06	·310
Albuminoid N.	·300	·069
Nitric N.	—	1·814
Oxygen absorbed in 4 hours 80° F.	4·14	·698
Dissolved Oxygen absorbed 24 hours	—	10·3%
Incubator test { before	—	·261
Incubator test { after	—	·263
Suspended Solids	6·7	2·1

(*b*) Same filter treating precipitated storm-water at the rate of 600 gallons per square yard :—

	Precipitated Storm Water.	Bed Filtrate.
Ammoniacal N.	1·38	·357
Albuminoid N.	·211	·103
Nitric N.	—	1·93
Oxygen absorbed in 4 hours 80° F.	1·95	1·05
Incubator test { before	—	3·10
Incubator test { after	—	·320
Suspended solids	7·2	7·1

(*c*) Same filter treating precipitated sewage at the rate of 200 gallons per square yard (March 1905) :—

	Precipitated Sewage.	Bed Filtrate.
Ammoniacal Nitrogen	1·68	·500
Albuminoid Nitrogen	·348	·070
Nitric Nitrogen	—	1·52
Oxygen absorbed in 4 hrs. at 80° F.	3·00	·581
Percentage of dissolved oxygen absorbed	—	13%
Incubator Test { before	—	·21
Incubator Test { after	—	·24
Suspended Solids	5·1	·8

(*d*) Same filter treating storm-water at the rate of 1,200 gallons per square yard (March, 1905) :—

	Precipitated Sewage.	Bed Filtrate.
Ammoniacal N.	1·71	·514
Albuminoid N.	·296	·108
Nitric N.	—	1·13
Oxygen absorbed in 4 hrs. at 80° F.	2·14	·860
Percentage of dissolved oxygen absorbed	—	27%
Incubator test { before	—	·362
Incubator test { after	—	·417
Suspended Solids	7.1	8·1

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22039. Have you observed the effect of changes of atmospheric temperature on the working of a percolating filter ?—I hand in a Table showing the average maximum and minimum temperatures for each month from July, 1904 to February, 1905, and also the variations in the percentage of purification. The filter was treating precipitated sewage, and consequently the filtrate contained very little suspended matter. I have chosen this example owing to this fact, for when solids are present in quantity in a filtrate the changes in purification due to changes of temperature are masked by the fluctuations in the suspended matter :—

Month	Temp. °F.		Precipitated Sewage.				Filtrate.						Percentage purification in Alb. NH_3.
	Min.	Max.	Amm. N.	Alb. N.	O. Abs.	Suspd. solids.	Amm. N.	Alb. N.	Nitrn. N.	O. Abs.	Percentage of dissolved O. absorbed.	Suspd. solids.	
July, 1904	54	70	1·91	·292	3·48	4·4	*·494	·107	·898	1·40	17	·8	* —
Aug. ,,	51	66	1·37	·190	3·55	5·7	·108	·038	2·02	·528	7	1·2	*79.9
Sept. ,,	46	62½	2·22	·264	4·24	6·1	·129	·045	1·82	·497	7	1·8	82·9
Oct. ,,	41	55	2·18	·314	5·08	8·4	·155	·052	2·17	·605	10	3·2	83·4
Nov. ,,	36	46	2·15	·357	4·17	5·7	·557	·081	1·84	·547	7	3·0	77·4
Dec. ,,	32	42	2·00	·377	4·35	9·8	·419	·094	2·14	·611	14	2·5	75·0
Jan., 1905	33½	42	1·82	·324	4·91	5·0	·428	·086	1·18	·725	7	2·2	73·4
Feb. ,,	35	45	1·88	·420	3.52	5·2	·438	·084	1·30	·480	5	1·0	80·0

Generally speaking these figures show that the purification is affected by changes of temperature for (1) the amount of ammoniacal nitrogen in the filtrate approximately increases with a decreasing temperature; (2) the purification in albuminoid nitrogen and the oxygen absorbed value decreases approximately with a decreasing temperature.

22040. Have you found any trouble from vegetable growths in percolating filters ?—Growths appear in quantity upon the surface of the continuous filters at Leeds in the early and later periods of the year when it is necessary to repeatedly fork the surface in order to prevent ponding of the liquid, and so keep the interior of the bed well ærated. These periods only last from two to three weeks, and during the remaining portion of the year it is not necessary (or, at least only very occasionally) to fork the surface. These growths are the same as are found upon the walls of the main sewers, and the fact that they only grow readily at particular periods upon the filters would seem to point to the sewage temperature, which is intermediate at these times, being the determining factor in their rate of growth or else in their season of sporing.

22041. Would you kindly compare the cost (initial expenditure and annual cost of upkeep and working) and relative advantages of percolating filters and contact beds. Do you consider that one form is best for some kinds of sewage, and the other form for other kinds of sewage ?—The relative advantages of percolating and contact beds are : (1) If solids are present in the liquid to be treated, a greater depth of filtering material is required for percolating filters than for contact beds. If no solids are present, the difference is not great. (2) Percolating filters cost more to construct than contact beds. (3) If solids are present in the liquid to be treated, they are present in the effluent from percolating beds, necessitating extra settlement or filtration. Contact bed filtrates are practically free from suspended solids. (4) As a general rule, the filtrate from a continuous filter contains more dissolved oxygen than that from a contact bed. (5) The amount of liquid treated per cubic yard per day on contact beds is limited by the number of fillings which can be given, and decreases in amount as the beds lose capacity. With percolating filters the amount treated is constant, and if the bed material is coarse and not easily disintegrated by weathering influences, this amount remains constant for many years. Accumulation of solids within the body of a contact bed produces in time a great loss in the water capacity, which can be effectively regained only by washing the bed material. With coarse percolating filters these accumulations may, in the course of time, produce bad internal distribution, but this is easily remedied by turning a large volume of water on to the filter and flushing out the retained solids. Generally speaking, the effective life of a percolating filter will be longer than that of a contact bed. (6) Contact beds are less readily affected by changes in atmospheric temperature than percolating beds.

22041*. Do you find that the chance of nuisance is any greater with one form of filter than with another ? Does the risk of nuisance depend on the kind of sewage which is being treated or on the nature of the preliminary treatment to which the sewage has been subjected ?—I have never found that the actual filtering operations cause nuisance. The risk of nuisance arising, in my opinion, depends upon the nature of the preliminary treatment and the method of distribution, *e.g.*, the process of distributing septic tank effluent upon filters by means of spraying devices may give rise to nuisance.

22042. Have you made any comparative observations which show how many gallons per cubic yard per twenty-four hours of your tank liquor or tank liquors, could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds ?—I have treated various liquids upon percolating filters at the following rates per cubic yard per twenty-four hours, with the production in each case of a good filtrate :—(1) crude sewage on a twelve feet bed at the rate of forty-two gallons per cubic yard; (2) septic tank effluent on a nine feet six inch bed at the rate of fifty-three gallons per cubic yard; (3) settled sewage on a nine feet six inch bed at the rate of sixty-one gallons per cubic yard; (4) precipitated sewage on a six feet filter at the rate of forty-eight gallons per cubic yard; (5) precipitated sewage on a six feet filter at the rate of 100 gallons per cubic yard.

With regard to contact beds, in order to produce a good result it has been necessary at Leeds to adopt double contact in every case; therefore, to obtain the amount of sewage treated per cubic yard under these circumstances, the total number of cubic yards in the primary and secondary beds must be taken :—(1) crude sewage treated by double contact at three fillings per day on three feet filters gave a rate of 128 gallons per cubic yard per twenty-four hours at the commencement of the

* 1st filtrates from a new filter and therefore cannot be compared with others.

experiment. At the end of two years the amount which could be treated under the above conditions was only twenty-nine gallons per cubic yard per day; (2) septic tank effluent treated by double contact on six feet beds, receiving two fillings per day and one weeks' rest in every four, gave an average rate for 1903 and 1904 of thirty-three gallons per cubic yard per day, the maximum amount being forty-two gallons. Generally the average amount treated per cubic yard per day throughout the life of a filter is greater on a percolating bed than on a contact bed; analytical figures are given in answer to previous questions.

22043. What, in your opinion, constitutes a good effluent? I consider that a satisfactory effluent must conform to the following conditions:—(1) it must be non-putrescible; (2) the free ammonia value must be low and the nitric nitrogen value high; (3) the suspended matter must be low.

22044. What are your views of the various tests used in judging of the quality of an effluent, and of the advisability of a standard or series of standards?—I am not in favour of fixed standards of purity based upon limiting numerical values such as the present Mersey & Irwell standard, for the reason that different bacteriological processes produce effluents, even when the same liquid is treated, containing varying amounts of organic impurity, as determined by the usual tests, the quantity of which is no safe criterion of the power an effluent possesses of resisting putrefactive changes. Thus with the "oxygen absorbed in four hours" test the highest value I have obtained with a non-putrescent double-contact bed effluent has been 1·62 parts per 100,000. Above that figure the effluents have invariably been putrescent. On the other hand a continuous filter, treating crude sewage, gave effluents having a value as high as 2·30 which were non-putrescent. An effluent which at one time is non-putrescent with a given "oxygen-absorbed" figure is sometimes found to be putrescent when giving a much lower figure. In the case of the "Putrescibility of an effluent as measured by the Incubator test," I find that, even with the addition of urea to decompose nitrites, the "three minutes oxgyen absorption" figures are unreliable, many effluents giving higher values after incubation than before, although remaining perfectly sweet. In all cases, however, where an effluent has really putrefied upon incubation, I have found that the "æration test" has also shown it to be putrescent, but when the effluent has remained perfectly sweet, although there has been an increase in the oxygen value of the incubator test, the "æration" test has shown it to be non-putrescent. I find that the most reliable method of determining the putrescibility of an effluent is by the "æration test." A really good effluent will not absorb more than 25 per cent. of its dissolved oxygen and a moderate effluent from 30 to 40 per cent. Above 50 per cent. all effluents which I have examined have been putrescent; any absorbing from 40 to 50 per cent. are doubtful in character. The free ammonia test is also very useful, for generally any effluent containing only a small quantity will be stable with regard to the "æration test." I regard the "oxygen absorbed" and the albuminoid ammonia tests as giving very parallel results with any particular sewage, and therefore, I do not consider it necessary to always determine both values. With regard to the amount of suspended matter in the effluent, I consider that a contact bed effluent should not contain more than three grains per gallon (4·2 parts per 100,000), and that a continuous filter effluent may contain up to five to six parts per 100,000, if the other tests are satisfactory, as the solids in this case are usually better oxidized than in the former.

22045. With regard to your answer to Question 21993, we have it from several witnesses that it is possible to oversepticise the sewage. You tell us that you have never found it so. Have you made several experiments?—Yes, but only in the general course of experimenting. I never tried it on contact beds. It may be possible there to oversepticise but I never found it so on continuous filters.

22046. (*Colonel Harding.*) You have in fact tried experiments for a considerable period with septic tanks at so slow a flow as would fill the tank in 72 hours, have you not?—Yes.

22047. And you did not find any material difference either in the effluent or in the evolution of evil-smelling gases?—No; it was practically a normal tank.

22048. (*Mr. Power.*) Are you disposed to think that the character of the trade effluent in your sewage has to do with the behaviour of the septic tank?—It may, for instance, be possibly owing to the larger amount of iron, which unites very rapidly with the large amount of sulphur in the sewage.

22049. (*Colonel Harding.*) You have not found that by largely reducing the flow there was a development of sulphuretted hydrogen?—In the gases given off?

22050. Yes?—No.

22051. (*Chairman.*) As far as you are concerned at Leeds, you think the septic tank might remain full for a week and the effluent would be just as easy to treat?—In one particular case—a good while ago now—we allowed a tank to stand for a month and began working it straight away on the contact beds and we found no difference at all.

22052. You found no difference?—No.

22053. After standing for a month you found no difference?—Of course, the tank became much more septic in condition.

22054. In your answer to Question 22000, there is a considerable difference with regard to the suspended solids —9·5 and 6·4?—That is probably due to the smaller amount of suspended matter going on with the lime effluent.

22055. Then with regard to Question 22018, the last analysis there is considerably better than the third analysis, is it not?—Yes, that is so.

22056. Have you any explanation of that?—Oh, yes, in the first case the beds received three fillings per day, but in the last case they received on the average only about $1\frac{5}{8}$ fillings a day. There was a much longer period of rest.

22057. Then on Question 22032. Have you found by actual experience that a filter with its base on the ground level would give worse results?—No. At Rodley we have a filter with its base actually under the ground level and simply aerated by vertical pipes down to the base, and in that case we get perfectly aerated results.

22058. In answer to Question 22032, you say it is desirable that the base should be above the ground level?—Quite so. If it is below the ground level there may be a danger of the access of air being easily stopped.

22059. But you have no actual experience of a filter with its base on the ground level having the access of air stopped?—No.

22060. (*Colonel Harding*). In speaking about the bottom of the filter being raised from the ground I think you mean that the material would be raised from the bottom of the filter. I do not think you mean to suggest that a percolating filter sunk into the ground would necessarily not be aerated if the same conditions applied?—No. I simply meant that there must be a given air space between the base of the material and the concrete floor.

22061. Such access might exist equally if the concrete was sunk into the ground?—Yes, we have it at Rodley.

22062. (*Chairman.*) In answer to Question 22036, you say that in practice it is possible to produce a result containing from four to five parts per 100,000 of solids. Have you any figures which would show the cost of that final treatment?—I have not with me, but I believe I gave some information to Mr. Willis some time ago.

22063. In reply to Question 22041, you state that percolating filters cost more to construct than contact beds. I suppose you are quite sure about that statement?—I think I am.

22064. Could you prove it by your own experience?—Only by the small experimental filters. It is the greater depth and the need for giving efficient aeration all round which causes the extra cost.

22065. (*Sir William Ramsay.*) Are you basing your experience on the Whittaker filters?—On most of the continuous filters.

22066. (*Chairman.*) In your opinion is the type of effluent from the contact beds superior or inferior to that from the percolating filter?—There is very little difference between the two effluents under the best conditions, but taken under the worst conditions—that is both beds

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treating crude sewage—and with settlement of the effluent from the continuous filter, then I have no hesitation in saying that the continuous filter effluent is much the better.

22067. (*Mr. Power.*) There are one or two points I should like to ask you about, though I am afraid they may prove to be rather engineering matters than appertaining to your department. They have reference to the storm waters. I should like to understand this a little more clearly. Your dry weather flow is 17,000,000 gallons ?—Yes.

22068. And one-third of that will be trade refuse ?—Yes.

22069. Then as to soil water you say that may on occasion amount to 3,000,000 gallons per day ?—Yes.

22070. Then that does not leave you a great deal for domestic sewage under present conditions ?—I mean that 3,000,000 to be added on to the 17,000,000.

22071. You do ; it is not included ?—17,000,000 I put down as the dry weather flow ; these 3,000,000 only come in after periods of rain.

22072. Mainly in the winter time ?—Well, if it is a wet summer we get it then ; it is a dilution which only occurs after periods of rain.

22073. The next point was Question 21959,—that the maximum capacity of the sewer is 60,000,000 gallons ?—Yes.

22074. Well, that is not six times ; not quite four, having regard to the seventeen plus three ; that is a good deal short of six times the dry weather flow ?—That is so.

22075. Does that mean that the capacity of the sewers will not bring you down more than 60,000,000 a day ?—They will not under the constructional conditions.

22076. One tenth of an inch of rainfall per hour in twenty-four hours will give you that continuously,—the whole 60,000,000 in a day, will it not ?—Oh, yes, we very often get the sewer full.

22077. Then how about the overflows ; are there a number of overflows in the town, and at what points do they act ?—They are along the whole line of the sewers ; of the main sewers.

22078. And would they come into operation before the rate of six times the dry weather flow was reached ; I suppose they would ?—Yes.

22079. Then in time of storm there would be a good deal of polluting liquid going into the river that never comes near the works ?—By means of the storm overflow.

22080. Therefore what you say at Question 21972, as to treating six volumes of storm water means that you are prepared to do that by your process if it is delivered to you to do ?—That is so.

22081. And as a matter of fact you have now and again treated six times the customary amount by those very filters, I suppose ?—That is so.

22082. On Question 21972 still, three volumes in the ordinary way ; that would be three volumes of precipitated sewage, would it ?—Yes.

22083. At the rate of 100 gallons per square yard ?—Yes.

22084. Then you deal with the balance ; the other three you say "well settled ;" is that simply settled by subsidence tanks, and if so, for how long. In the lower part of Question 21972 you say : "I think the case would be fully met by treating three volumes as in the ordinary way, the remaining three volumes being well settled or precipitated"—and then you propose to treat that additional three volumes from 600 to 1,200 gallons per square yard ?—I mean there, really three volumes by the ordinary method of treating sewage water, by precipitation or whatever method of filtration.

22085. It would be at the rate of 100 gallons per square yard, the normal rate ?—Yes, 300 gallons.

22086. I want to know what you do with the balance you spoke of as being well settled ; is it in subsidence tanks, and if so for how long ?—It is about a four hours settlement for the storm water sewage.

22087. Would that require a very large instalment of tanks to deal in that way with the whole of the storm sewage of Leeds ; it would be on rather a big scale, would it not, four hours settlement. You see, it would be more than 60,000,000 gallons coming down when the sewers are enlarged, and the middens are converted into water closets ?—Oh, that is so, but I think if you add a little more precipitant you can do it with a 12-hour tank.

22088. You would use precipitant ?—I am using, here, only a little.

22089. Well settled or precipitated ; would you use some precipitant with it ?—Yes ; I was saying if you use precipitant you would treat the whole six times in the tank, which at normal times was a 12-hour flow—that is half 24-hour septic tanks.

22090. (*Sir William Ramsay*). Giving it 4-hour periods ?—Oh no, it would be two in that case.

22091. (*Mr. Power.*) And when you are treating this storm sewage at the rate of 600 to 1,200 gallons per square yard ; I see you have got out some very favourable figures ; are those effluents non-putrescent, generally ?—Quite non-putrescent.

22092. They are ?—Yes. I must say that I have been surprised myself at the character of the results I have obtained by this experiment.

22093. The bed is in no way damaged by running it to the extent of 1,200 gallons per square yard, for the best part of a day ?—I have had it going for two days without hurting the filters.

22094. Continuously ?—Yes.

22095. Without any damage to the subsequent filtrating ?—None that I could determine.

22096. (*Sir William Ramsay.*) Is there much subsoil water in the Leeds sewage ? In your answer to Question 21960 you have a very high maximum ; is that subsoil water ?—That is subsoil water, but it only occurs after long periods of rain.

22097. I suppose the septic tank liquor contains a quantity of iron in solution, or colloidal solution ?—It does.

22098. That has to be decomposed by the sulphuretted hydrogen, or rather there will be a double decomposition ; the albuminoid bodies will decompose and give sulphuretted hydrogen. Will that attack the iron and form a sulphide of iron ? I think you said, in answer to some other question, in no case have you had a smell of sulphuretted hydrogen ?—Not in the tank.

22099. That means that there is more iron than is sufficient to deal with it all ?—I have iron in solution in the septic tank effluent.

22100. However long it has been running ?—Yes.

22101. So that Leeds stands in a peculiar position as regards the nuisance likely to be caused by the septic tank. You will never have sulphuretted hydrogen ?—Oh, I think we stand in a very favourable position from that cause.

22102. In answer to Question 21964 you say that the suspended solids are more or less dark brown in colour ; have you estimated the inorganic matter in the solids ?—Is that from the ordinary sewage solids ?

22103. Yes ?—Roughly speaking, there will be about 50 per cent.

22104. Half of each ?—Yes.

22105. In the answer to Question 21965 you give oxygen absorbed in four hours, 10·8 : is much of that due to ferrous iron ?—Yes, there is some ferrous iron in the sewage.

22106. Can you give any information as to how much of the 10·8 is due to ferrous iron ?—I cannot, because the bulk of the iron enters the sewage in its ferrous state, but during its passage down to the works it becomes oxidised to some extent, and that varies very largely.

22107. In reply to Question 21972 you speak of a specially constructed storm water filter ?—Yes.

22108. You do not give any details as regards its construction ; what sort of filter was it ?—It is simply built on the usual contact-bed form.

22109. (*Colonel Harding.*) Is it on the lines suggested by the Local Government Board ?—As far as I understand them, it is.

22110. (*Mr. Power.*) What depth ?—Three feet.

22111. (*Sir William Ramsay.*) Is it filled ?—Yes.

22112. How does it work ?—We close the valves—the outlet valves—and run the storm water into it till the bed is full to the surface ; we then open the outlet valve to such an extent as to deliver the same volume of water that is going on to the filters.

22113. And you really use it as a continuous filter ?—A streaming filter, yes.

22114. In your answer to Question 21975c you describe the method of separating the sludge ; what becomes of the water that drains off the sludge ?—It drains back into the tanks.

22115. Some evaporates, I presume ; not much evaporates ?—Well, it can only do so from the top surfaces ; the top surfaces of the sludge very quickly become hard, but even when the top layer is sufficiently hard to walk across, the sludge beneath is quite wet.

22116. Then that must dry by evaporation ?—The top layer.

22117. And ultimately the under layer ?—It takes a long time.

22118. (*Colonel Harding.*) Does it take many years ?—To dry it by evaporation, I am afraid it would. I have tried it in small lagoons, just drying by evaporation, and even there, where the layer was a foot thick, it took several months.

22119. (*Sir William Ramsay.*) I remember you used to spread the sludge in thin layers in some way or other over a considerable surface of ground, and then, I think, it dried ; is not that so ?—If you can spread the sludge in thin layers, say six inches thick to begin with, it very quickly dries, then cakes ; as the water evaporates from the surface layer, the sludge at Leeds has a tendency to crack somewhat into cubes, so that air gets practically through the whole mass in time.

22120. Is the soil at Leeds sufficiently porous to make it possible to hope that the soil would act as a kind of filter, and a lot of water would get into the soil ?—I am afraid it would only answer once ; the soil would become clogged up.

22121. With the sludge ?—As a matter of fact we have to put a fresh layer of clinker at the bottom of the lagoon after clearing it out.

22122. In your answer to Question 21978, you say: "Recent experiments at Leeds have shown that an effluent produced by using eight grains of lime per gallon and two grains of sulphate of alumina, and practically free from suspended matter, can be treated more easily than septic tank effluent or settled sewage upon trickling filters" ?—Yes.

22123. That is not everyone's opinion ; I think we have had contradictory evidence to that ?—Well, as you see from the analyses, the results are well below the Rivers Board's standards.

22124. Yes ?—In both cases. In the one case where a septic tank effluent is treated on the filter, you get 10·5 parts of suspended solids in the effluent. Of course that necessitates a further process for draining off those solids. In the other case, where precipitated sewage is sent on to the filter, practically no solids appear in the effluent. Again, the gallons treated per cube yard are in the case of septic tank effluent 61 gallons ; in the case of precipitated sewage, 100 gallons.

22125. You do not mention the details of the septic tank liquor there at all ?—No, I have given them in another place.

22126. Is it the same liquor as you mention in answer to Question 22000 ?—Yes.

22127. That is the same liquor ?—Practically the same composition, yes.

22128. It might be advisable to refer to Question 22000 there ?—No, that is the filtrate from a bed treating septic tank effluent.

22129. Septic tank liquor that goes on ?—Septic tank liquor. I give it in the part dealing with septic tanks.

22130. (*Mr. Power.*) Is it not under Question 21992 ?—You get there the analyses for several rates of flow.

22131. Different flows ?—Yes.

22132. (*Sir William Ramsay.*) Would it not be well, in answer to Question 21978, to give the figures for the liquor ?—You get it at Question 21989.

22133. Then we might put a note to Question 21978 to say that this liquor is alluded to in the answer to Question 21989 ?—Yes, the open tank.

22134. In your answer to Question 21979 you say, "The most effective precipitant was a mixture of ferric salts and lime, closely followed in order of merit by aluminium sulphate and lime." What is the theory of those precipitants, ferric salts and lime ? Is it merely enclosure by the precipitated ferric oxide of the albuminoid matter ?—I take it so.

22135. That is all ?—I think so.

22136. Is oxidation that goes on due to ferric salts, do you think ?—I have not noticed any.

22137. Because it is rather unusual ?—The ferric salts ?

22138. No, that the most effective precipitant should be that ?—Well, what I mean is that it clears the liqiud in the shortest time.

22139. Well, naturally ?—There is very little difference between it and aluminium sulphate and lime.

22140. In answer to Question 21985, you say that the sludge does not contain an appreciable amount of chemical poisons. May I ask what you tested for. You mentioned an enormous quantity of arsenic coming into the sewage ; did you test for that ?—Yes, it is very small when mixed with the whole bulk of the sludge.

22141. Was there anything noticed as regards the clogging of the beds to which you refer in your answer to Question 22000 dealing with the single contact beds ; did the bed treating septic effluent clog more or less rapidly than the bed treating lime and sewage ?—No, the clogging in both of these beds was rather peculiar. After working several months, they lost a large part of their capacity ; I can give you the figures in a moment. The bed treating lime precipitated sewage had an original water capacity of 55,000 gallons. That was in March, 1899, and by October 20th of the same year the capacity had dropped to 21,000.

22142. What about the other ?—In the other case we started in March with 29,000 and dropped to 10,000.

22143. (*Mr. Power.*) In six months ?—By the end of September in that case.

22144. (*Sir William Ramsay.*) Practically the same period of time ?—Now in both of those cases the beds were rested, and the whole of the material was turned over, and in the first case the capacity rose from 21,000 it was in October to 53,000, very nearly the same as the original water capacity.

22145. What about the other one ?—The other one rose from 10,000 to 26,000 ; that was within 3,000 of the original water capacity. Considering the beds had had so little suspended matter on, we concluded that the loss of capacity was due to the material consolidating together.

22146. We have been told by one witness that it is a comparatively inexpensive matter to renew these beds by taking off the old material, rejecting the smaller portion, washing it and putting it back. We got exactly contradictory evidence from another witness, saying it is far too expensive an operation to be contemplated. Which is right ?—Well, if we use destructor clinker, which we can get for nothing, and put it in our contact beds, it would cost us to get into the bed between 4s. and 5s. a cube yard. If we renew that material say every four or five years the annual cost is going to be something enormous. If we wash it, we shall certainly lose a great bulk of the material. And then in addition to the cost of washing, which will probably be about 1s. 6d. to 2s. a cube yard, we shall have to replace the material washed away at a further cost of 5s. per cube yard.

22147. Then which would you regard as the more practicable ; is it necessary to replace the beds after four or five years working ?—It is necessary to do something to them. If you turn the material over you will get an increase of capacity, but the next time you turn it over, a few years later, you will not get such a large increase of capacity—in fact with one or two beds at Leeds we got a very small increase of capacity, so that once turned over you will either have to take the material out and renew it, or else wash it ; there is no other course open.

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22148. Comparing these contact beds with continuous filtration, is it necessary to replace your continuous filters in the same way?—If your material disintegrates it is.

22149. Is there as much disintegration in the one case as in the other ?—I think it does occur in the case of a continuous filter.

22150. The disintegration is greater in the continuous filter ?—Well, I will not say it is greater, but the effect of it shows in a much shorter period of time.

22151. But would it be necessary to wash out a continuous filter, or add to the top ?—I am afraid not ; the whole objective of the filter should be to keep the liquor equally distributed throughout the whole filter ; if you have disintegration or consolidation you will get watercourses through the filter, which would produce a bad effluent.

22152. Without washing the substance ?—If you screened off the fine, broken-down material, I think it would do.

22153. That would be cheaper than replacing a contact bed I presume ?—I could not say.

22154. How do you keep the surface of the tanks free from scum ?—We allow the scum to form in the first instance. When we have got a continuous layer, we cut out a strip along the side of the tank in the direction to which the prevailing wind is blowing. We remove that strip by hand, and the wind carries the bulk of the scum to the side again. Then we cut off further strips till we clear the tank.

22155. In answer to question 22016 you say, "The rate at which primary contact beds lose their capacity varies directly with the amount of suspended solids in the liquid treated." Have you worked this out from the suspended solids going on during the period ?—Perhaps I should not say direct proportion, but it is in proportion to the suspended solids treated.

22156. That is to say that it is not a numerical proportion ?—Oh no, I did not intend it to mean that at all.

22157. And again, in this other answer in italics : "The rate is in the inverse ratio to the amount of rest" ? —The same applies.

22158. The same applies ; it is a general statement ?—I only meant it for a general statement.

22159. It is not intended to be numerically accurate ? —No.

22160. I wish to refer to your answer to Question 22021. I suppose you would imagine that oxygen gets into a contact bed from above during the period of rest ? —Resting full or empty ?

22161. Empty ?—Only by diffusion.

22162. Do you imagine that it is carried in when the bed is being emptied ?—Yes.

22163. That is where the oxygen comes from ?—I think so.

22164. Part of the solids are oxidised when the bed is full, and part of the retained liquid when the bed is empty ; has that been proved or is it merely inferred ?—It is inferred from the general facts gathered.

22165. Do you think that the choking of your beds is due to any extent to the presence of iron—to your exceptional conditions in Leeds. Would beds elsewhere, where there is less iron, choke equally quickly ?—I will not say equally quickly.

22166. Do you get much oxide of iron ?—Oh yes, in some cases we have found the bed material cemented together in large blocks.

22167. By the iron ?—By the iron.

22168. So that after all, your answer with regard to the lasting of the beds cannot be taken as general, but only as applying to Leeds ?—I only mean all these answers to apply to the conditions prevailing in Leeds.

22169. In your answer to Question 22024 you say that the depth of the filter should vary according to the amount of solid in the liquid treated. Well, that is a very important point ; has that been proved definitely with various amounts of solid ?—Yes, I think so ; we have tried screened sewage, septic tank effluent, ordinary settled sewage containing approximately the same amount of suspended matter as septic tank effluent, and clarified sewage ; we have tried those four on continuous filters, and to get what might be looked upon as equal final results within experimental limits we have had to have different depths of bed material.

22170. So that it comes to this,—that the difficulty of purifying sewage is the difficulty of purifying it from solid matter ?—The great difficulty is in purifying it sufficiently from solid matter.

22171. And if the solid matter is removed it becomes a much simpler problem ?—There is no difficulty at all then.

22172. In answer to Question 22027 you say the feed should if possible be continuous. Again, have you any definite proof of that ; have you tried both ?—We have tried both.

22173. On the Whittaker ?—On the Whittaker.

22174. And do you find when you have rushes that it does not sprinkle ?—We find when we have intermittent feeding, the arm stops at one place until it gathers momentum to enable it to swing round again.

22175. It forms channels, no doubt ?—Well, it gets washed through at that particular portion of the bed.

22176. I wish to refer again to Question 22031. Can you give any details as to the filter that you use without that side aeration : was it a large experiment ?—12 feet square, 10 feet deep, and the walls were blank, and the only aeration was a 6-inch valve at the bottom of the filter.

22177. What size of material—coarse or fine ?—About 3 inches diameter—coke.

22178. Is that what we saw as the continuous filter—the Leeds filter?—The first one, I daresay it would be.

22179. In answer to Question, 22044, at what temperature have you carried out the aeration test ?—Laboratory temperature.

22180. Ordinary temperature ?—Without dilution of the effluent at all.

22181. (*Major-General Carey.*) Question 21972, referring to a comparison of the results of storm water filtrates, the storm water in the experiment of March, 1905, was precipitated and filtered at the rate of 1,200 gallons per square yard ?—Yes.

22182. But in the second experiment at the rate of 500 gallons per square yard ; it was only screened before treatment on filters ?—That is so.

22183. Therefore the more favourable result was produced at considerably greater cost ?—I hardly think you can compare them in that way. The experiment on the special storm filter was supposed to follow the recommendations of the Local Government Board, that is to treat three volumes on your ordinary filters, and the remaining three volumes on special storm filters. I here show that if precipitation is included in the general method of purification for a works, that if all the storm water were settled in the ordinary precipitation tanks, then it can all be treated on the same filters as are used to treat the normal flow of sewage without having recourse to a further set of storm filters.

22184. That presupposes having tank capacity sufficient to treat the whole of your sewage and storm water ? —Certainly.

22185. Now, Question 22016, you give an example of the way in which loss of capacity occurs. In a primary bed working under ordinary conditions the capacity in that bed is very rapidly reduced per annum. In two years it would be choked altogether, or the capacity would be *nil* ?—Before you come to that point you would find the difficulty cropping up of getting the liquid into the filter.

22186. You would not get anything in ?—I mean to say the surface gets so clogged that though you may have an apparent water capacity it would take you so long filling your bed that the bed is useless.

22187. Quite so. Now, I want to know whether you would work that bed to the extreme limit, or would you take the materials out and wash them at a certain intermediate stage ; when the capacity is being reduced at that rate how are you to regain capacity ?—

Well, you cannot do it by resting. You must do it by washing the bed and replacing the material.

22188. Would you let the bed go on until it became impossible to work it any longer, or would you take it in the intermediate stage, and take out the materials and wash them ?—That is a point I can hardly answer.

22189. As far as I can make out the cost per acre bed was at 2s. 5d., which works out to about £600 per acre. Would you take it rather under that if you had to introduce fresh material ?—You mean plus that ?

22190. Or if you had to introduce fresh material ?—It would cost us at Leeds about 4s. or 5s. per cubic yard for fresh material.

22191. You mention 2s. 5d. as the actual cost ?—That is for washing only.

22192. In any scheme of biological treatment it would be always necessary to provide a considerable margin of area beyond what is actually required for the treatment in order to rest the beds, is not that so, whether contact beds of percolating filters ?—You certainly want a little elasticity in your scheme, but I do not think you need it to the extent of having a large surplus.

22193. If you rest the percolating filters once a month ? —But I do not rest them at all.

22194. I thought you did rest them ?—No, I rest contact beds once a month.

22195. But you said the percolating filters ?—Not now that I am treating storm waters; they are working day and night without any rest at all.

22196. (*Colonel Harding.*) When you are treating septic effluent do you not work them day and night for several years ?—Yes, only stopping when storms were on. We do not treat storm waters on them.

22197. (*Major General Carey.*) This is what I am referring to; Question 22036, such a filter—you are referring to percolating filters—will continue to treat, a filtrate containing about eleven parts per 100,000 of solids for a period of about one month before it becomes necessary to stop the flow on it ?—That is referring to the small straining filters for taking the solids out of the continous bed.

22198. It does not refer to the continuous filters ?—Not to the continuous filter but to the straining filter afterwards.

22199. (*Sir William Ramsay.*) May I ask one further question before we pass on. You have considerable experience, I suppose of the sprinklers for putting sewage on to the filter bed ?—I know one or two forms.

22200. Do they require very frequent picking out of the holes; does it amount to much labour ?—At Leeds we make the holes very large; we make them larger than they are delivered to us by the makers; in that case we have to clean them about once a day.

22201. What do you call large; what diameter ?—In the case of the large continuous filter we have there they will be half an inch wide at the end of the arm, the end away from the centre, going down to about $\frac{3}{8}$ inch at the centre.

22202. And these have to be picked out once a day ? —We do it by rodding the arm out.

22203. From the inside ?—Yes, we send a rod up with a lump of waste on the end.

22204. Does it take long; do you take off the arm ? —No, we can take off a cap at the end.

22205. Push the whole of it back into the centre ?—Yes.

22206. Does it take long ?—No, about ten minutes will do it perfectly.

22207. The whole of them ?—One.

22208. One rod ?—Well, we have only two arms to deal with.

22209. I see. What I want to get at is, is it conceivable that a sprinkler can be used without a very great deal of mechanical labour being required to clean it daily ?—Wherever you have holes in a sprinkler arm you will have labour.

22210. Is it serious ? We were told by one of our witnesses that there is a plan of sprinkler for continuous filter which is probably to be adopted over acres. Does it not involve an enormous amount of mechanical labour in cleaning those holes which he told us were as small as one-sixteenth inch rising in size ?—One-sixteenth is too small; they would clog easily.

22211. It would be a very expensive method ?—I think if you have large holes it will not be a very serious cost; you will have to have men on the works.

22212. They might just as well be doing that as anything else ?—They might fill up their time in that way.

22213. (*Mr. Stafford.*) Referring to your answer to Question 21966 how do you estimate the strength of the sewage; you speak of the sewage at Leeds as not strong; have you any particular method of estimating the strength of it ?—I state in the answer to Question 21966 that it is not strong with regard to organic impurity. That is as far as I prefer to go.

22214. Yes, but you have no particular test or method of estimating the strength ?—No.

22215. In Question 21972, there is an analysis; is this the analysis of the effluent of the storm filter ? —Yes, with the storm water streaming through it.

22216. Do you find that the nitrates come out in a storm water filter when the beds have been flooded ?— I do not understand the question.

22217. Do you find that a good deal of the nitrates come out in large quantities when the beds are flooded ?— Well, you see by the analysis we get nitrates.

22218. I see you get nitrogen 0·624 ?—Yes, that is the average of a great number of experiments. Of course, the nitrates, I have no doubt, are formed when the beds are resting between storms.

22219. Is that continuous or does it come in rushes ?— The storms ?

22220. The amount of nitrates coming out; does it come out in rushes at the beginning or is it continuous ?— Oh, it is continuous, gradually tailing off as the storm continues.

22221. How long does it continue ?—I have never found the effluent without nitrates.

22222. In the same proportion ?—It would start at a higher value than this and gradually get less.

22223. In answer to Sir William Ramsay about the cost of washing and the cost of replacing new material, I understood you to say that the cost of washing was about 1s. 6d. per cube yard; is that it ?—I pay for it 2s. 5d. without mechanical appliances.

22224. And the cost of the new material was about 5s. ? —About 4s. to 5s.; that is to grade and place in the beds.

22225. Do I understand that there would be that amount of saving, the difference between 1s. 6d. and 2s. 4d. and 5s. in your method ?—No, because in washing you will certainly wash away some of the fine broken down material which you will have to replace.

22226. I understand that, but the amount of washed material; there will be that amount of saving on the washed material; the difference between 1s. 6d. and 5s ?— No, the difference between 1s. 6d. plus the cost of the material necessary to be added to bring the bed up to its old level, and 4s. and 5s.

22227. Yes, but still there is a decent saving ?—Oh, there is a distinct difference, certainly, on the side of washing the material if it can be done for 1s. 6d. on the large scale.

22228. (*Colonel Harding.*) It was suggested yesterday by a witness that washing was not only not prohibitive in cost but that it was actually desirable for new material, that there was a positive advantage in washing of new material, with the idea of getting out of it broken down portions of the material, and selecting by that means the better sort to be kept in the bed. Then it was pointed out to us by a witness, who had carried it out on a fairly large scale, that after washing material when the bed has become to a certain extent choked you wash away the broken down portions of the material, that what is left is far better than the original material. I think that your view is that it is practicable to wash materials ?— Oh, yes.

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22229. And that you would get a sufficient quantity of material after the washing to fill the greater part of the bed ?—Certainly.

22230. You would not require at most more than, shall we say, a quarter of new material ?—I should not like to give any figures.

22231. Well, you have tried some experiments, can you not express an opinion ?—Yes, but the material I washed had been well graded and well sifted before it had been used, and it had been used in a contact bed before I washed it.

22232. You had no opportunity at Leeds of trying any extensive experiments in the washing of filtering material ?—No.

22233. Turning back for a moment to the point raised by Sir William Ramsay as to the presence of iron in Leeds sewage, and the fact that it makes the Leeds condition somewhat special, could you tell us to what extent iron comes down in the Leeds sewage. Could you give us a figure for instance expressed in metallic iron as to the amount of ferrous sulphate that comes down ?—In broad figures we should get about 4 tons of metallic iron a day coming down with the sewage ; that is, roughly speaking, about 4 grains per gallon.

22234. That, of course, is a very considerable quantity ? —Yes.

22235. And must to some extent modify the results obtained at Leeds in comparing them with the results obtained where iron does not exist in the sewage ?—Oh, without doubt.

22236. On the other hand there are many towns, as in Leeds, where a good deal of such matters come down in the sewers ; one might instance Birmingham, Sheffield, and many others ?—Yes, that is so.

22237. Now, with regard to the presence of iron, which would appear to be the most convenient form of filtration, contact filtration or percolating filtration ?—Percolating.

22238. And probably because you have found that in the contact filtration the iron deposit has acted as a cement ?—That is so with regard to contact filtration.

22239. Cementing together parts of the material so as to make in effect one block ?—Yes.

22240. On the other hand in percolating filters the iron which comes out of solution into suspension takes a granular form and comes out in the filtrate ?—That is so.

22241. Is that due, do you think, to the better oxidation arising in the percolating filter which changes the iron from the ferrous into the ferric state ?—There is no doubt that iron is better oxidised in its passage through a percolating filter.

22242. Is ferric sulphate less soluble than ferrous ?—(*Sir William Ramsay.*) It is the other way round, (*Col Harding.*) But in fact the iron coming out in the percolating filter is in the ferric state ?—Yes, but in a basic-ferric state ; it is insoluble altogether.

22243. Insoluble ?—Yes, in the percolating filter effluent, which is giving satisfactory results, there is never more than a trace of iron in solution. Immediately the bed begins to fall off then iron begins to appear in solution.

22244. Then at Question 21962 * you alluded to the fact that the effluent from contact beds at Leeds were apt to be strongly yellow and often very unsightly, giving rise to flocculent subsequent decomposition. Had these observations applied rather to the time when you were using your contact beds for more or less crude sewage ?—Oh, that is so.

22245. When you were using on the contact beds septic effluents that would not arise ?—I have never had it yet.

22246. And in fact the effluents from contact beds when you were using septic effluents were extremely good ?—Quite as good as I have obtained from any method of filtration.

22247. There was no yellow colour and no subsequent decomposition and flocculent matter ?—None at all.

22248. You found that passing sewage through a septic tank caused a very great improvement in that respect ?—Yes.

22249. Passing on to the question of storm waters and your answer to Question 21970 you give there certain analyses ; in the first instance, four periods of storm, each of which had lasted about 20 hours. Are those averages spread over the whole duration of the storm, or are they simply averages of one analyses taken in regard to each ?—Oh, no, they are averages for each storm.

22250. What I wanted to get at was this, are the averages from analyses taken, say, at the beginning and at the end of the storms ?—In fact during the storms, and were taken away every half hour.

22251. These are really over the whole duration of the storms ?—Yes.

22252. Taking these over the whole duration, you observe that on the average the storm waters practically contained the same amount of suspended matter as ordinary sewage ?—That is on the average.

22253. That is taking it on the average ; taking simply at the beginning, the middle and end of the storm ?—Yes.

22254. You do not suggest that the amount of suspended matter at the beginning of a storm would not be much greater ?—I think the tendency of these analyses go to show that.

22255. The beginning of a storm, the very beginning of it, does bring down a great deal of suspended matter ? —Yes.

22256. And the analyses which you have given, which immediately follow your answer to Question 21970, go to show that when you have withdrawn the suspended matter from storm waters you have to deal with the liquid which is greatly less impure than ordinary sewage which has been precipitated ?—Yes.

22257. Roughly speaking about half the strength ? —Yes.

22258. The settlement of the suspended matter in storm waters is the essential treatment to be followed ; is it not in your opinion ?—To remove the suspended matter, yes.

22259. Then, when that has been done, if it is necessary to carry the purification further, is it more conveniently done on contact or on percolating beds ?—On percolating beds.

22260. Why ?—On contact you are limited to the number of fillings you can give per day. Percolating is simply a case of increasing the flow on to the filter.

22261. Then, on contact beds, if you increase the fillings too far there would be no adequate period of rest and of aeration ?—No.

22262. If you exaggerate the treatment on contact beds to the point of streaming storm water through them, there is practically no biological action at all ?—There would not be after the process had been continued for some time.

22263. What you mean is that during the period of rest the bed will have accumulated nitrates and so on, but those will soon get washed out ?—Yes.

22264. And after that there will be probably no oxidation ?—That is so.

22265. The experiments that you tried at Leeds with streaming filters as a single process for the treatment of storm waters did not appear to have given very good results ?—They are not nearly so good as the treatment of precipitated storm waters on the continuous filter.

22266. Even with regard to the withdrawal of suspended matter ?—That is so.

22267. Of course, on the other hand there is this to be said that the sedimentation of storm waters involves the production of a great deal of sludge which is always a trial and a trouble, is it not ?—Yes.

22268. I want to ask you a question which you may not be able to answer because possibly you may not have given attention to it, but it would be interesting to us to know if you are able to tell us in regard to Leeds what would be the proportion of storm waters in a year and the dry weather flow in a year. For instance if you take this to be 100 what figure would you have to add to that to represent the storm waters in a year ?—I could not tell.

22269. I am under the impression that about 50 per cent.; but of course, if you have not at hand the tables do not attempt to answer ?—No; I have here a table showing the average number of days on which various amounts of rain fell.

22270. That is the only way at which you can get at the information I want ?—Extending over a period of four years.

22271. Do those tables enable you to answer my question ?—I do not think so. The average number of fine days, 199; number of days that rain fell to only 1·1., 85; the number of days under 2 inches.

22272. I am afraid your giving us those figures will not help us ?—No, I am afraid not.

22273. Because it is necessary to digest them and calculate out the conclusion. At Question 21974 you give us a very interesting result of experiments in stagnant settlement of sewage, and it would appear that stagnant or quiescent settlement of sewage is remarkably effective as compared with flowing settlement, and in the first half hour, not to say in the first quarter hour, the bulk of the suspended matter is thrown down ?—That is so.

22274. It would seem to be possible by quiescent settlement of sewage and a comparatively small area of tanks to reduce the suspended matter down to 8 or 9 parts per 100,000 ?—Yes.

22275. And the reason why quiescent settlement is not universally adopted is probably the fact that there is a loss of head equivalent to the depth of the tanks, and that in most cases that would involve pumping up again ?—That is so.

22276. But where the levels permit you think highly of the quiescent settlement ?—It certainly gives a very good result and should be borne in mind.

22277. In the case of quiescent settlement, of course the idea would be to empty the sludge out every 24 or 48 hours ?—To clear out the sludge, yes

22278. You have not tried any experiments at all in this direction to septicise, not the sewage, but the sludge ?—Not with success.

22279. As a fact you have not tried an experiment at all ?—No, I tried to get septic conditions in the sludge and I could not; I gave it up.

22280. Tell us about that. It would be rather interesting, how did you try ?—I took an ordinary settlement tank, filled it full of water and ran in sludge produced from a small quiescent settlement tank, and I inoculated the tank with septic sludge out of our ordinary septic tank. I never got septic conditions occurring.

22281. In what period of time ?—Two months.

22282. But did you not, once, in some earlier evidence that you brought before us, tell us a case in which you had had a settlement tank entirely filled up with deposit, and you were unable at the time to empty it, and you let it alone for a month or more and the septic conditions developed rapidly, and the matter which at first stood up in islands on the surface of the water gradually settled down and became more or less liquid and septic ?—That undoubtedly did occur, but in that case I induced septic action by running continuously through it a small flow from a septic tank.

22283. A very small flow indeed, was it not ?—A very small flow.

22284. On this point of treating sludge septically, would you not empty successive tanks for a flow going through, and when the septic action had been once set up would it not continue ?—I would hardly like to say.

22285. You have not the necessary information to answer ?—No.

22286. But you think probably it is a point that might be worth investigation ?—It is certainly a point worth attention.

22287. In Question 21994 you referred to the effect of atmospheric temperature upon septic action and you give us details of a small experiment in which you gauged the gases given off from a septic tank from a certain area ?—Yes.

22288. And in summer you found that the gases given off are represented by the figure 37; in winter by the figure 13 ?—13.

22289. That is a striking difference in the production of gas ?—Yes.

22290. Could it be in any way accidental, think you ?—No, I do not think so.

22291. You think it was due to the difference in temperature ?—There certainly is a large difference in the amount of gas given off from a septic tank in summer and winter.

22292. On the other hand, you did not find, did you, in your experiments, that where you heated septic sewage you brought about greater septic action ?—Oh, in that case I heated the sewage going into a series of separate tanks, and got very little difference between the results in any case.

22293. You had a number of septic tanks, one of which was at the normal temperature ?—Yes.

22294. And others at increasing temperatures due to the injection of steam ?—Yes.

22295. And the last one was at the temperature of 100° F. ?—Yes.

22296. And in that case you did not find more digestion of suspended matter ?—No, certainly not; I think it was rather less than the normal tank.

22297. It seems a result which is a little out of harmony with the other one about the summer heat producing more septic action than in winter ?—It may be due to the injection of steam; the injection of steam into the sewage, going into the tank, may have had a sterilizing effect upon the sewage.

22298. But from your observations with this experimental tank and with the large area of septic tanks you had at Leeds, you have very little doubt that in summer the septic action is greater than in winter ?—Taking the gas as the factor, yes.

22299. A special feature of your experiments with percolating beds at Leeds appears to have been the abandonment of fine material and the subsequent successful use of coarse material ?—Yes.

22300. Something was said to you in cross-examination just now about the choking up of percolating filters; that choking up you only found when the material was too small ?—Was disintegrated.

22301. Or where by disintegration it had become too small ?—That is so.

22302. Given a material which will not readily break down and which is sufficiently coarse, a percolating filter may go on almost indefinitely, and it is only limited, is it not, by the degradation of the material ?—So far that has been my experience.

22303. In the case of a percolating filter as compared with a contact filter, no doubt the question of degradation applies in both sorts of filtration, only in the case of contact filtration you have the additional difficulty of the accumulation of undigested matter ?—Yes.

22304. Whereas in a coarse percolating filter, may I take it that the undigested matter does not in any way tend to accumulate; it passes through the filter ?—Not if there is disintegration occurring.

22305. No; but I am assuming that you are getting a material which is fairly free from disintegration; it is merely a question of theory at present ?—In that case there ought to be very little accumulation, at least permanent accumulation.

22306. You remind me of a point of some importance to bring out and that is this; in flowing at the dry weather rate through a percolating filter there is a pretty steady accumulation of suspended matter in the filter ?—Yes.

22307. But it does not remain there permanently ?—No.

22308. It comes out does it not ?—We get an increase in the amount of suspended matter in the effluent about twice a year.

22309. Tell us about these occasional flushes and what you attribute them to ?—I think I answered that, I have given that in answer to one of the questions given here.

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22310. Perhaps you will just briefly repeat it, will you ? I think you said it was due to the developemnt of certain forms of life at certain periods. What I wanted you to do was to precise a little more what those forms of life were ?—In reply to Question 22037 the answer is given there.

22311. I want you more particularly if you are able, to tell us what the special forms of life were ?—Worms chiefly and a larger larva.

22312. Such as ?—Well, we get the larva of certain beetles in the effluent and psycoda.

22313. Immense numbers of them ?—Yes.

22314. And you find the action of these forms of life is to disturb the matter deposited on the surface of the material, and having so disturbed it to bring it out by the flow ?—The only reason why I say that is that the flushes occur at a period when you would expect them, if this idea is correct.

22315. Then matter left behind by the normal flow of a percolating filter, provided the filter is built of sufficiently coarse material ultimately comes out either by the occasional flushes such as you have referred to, or by increased flow at storm times ?—That is so.

22316. And therefore the main difficulty in regard to the material of percolating beds is the getting of a material which will not rapidly disintegrate ?—That is the great difficulty.

22317. I think you found that the storm destructor clinker at Leeds was extremely friable ; some parts of it ? —Oh yes ; a bed built of very coarse material only lasted two years.

22318. The great thing therefore is to find a material which shall be, as far as possible, permanent ?—Yes.

22319. I understood that you were going to try at Leeds some experiments with spherical material of hard burnt clay ?—I have some on the works now but not sufficient to start an experiment.

22320. You are expecting to start an experiment soon ? —As soon as I get the material.

22321. You will probably expect with hard burnt clay there would be comparatively little degradation ?—Yes, I expect to have the same result that we get with a bed made of gravel.

22322. You get considerable permanence of material ? —Yes.

22323. And that is a vital point ?—It is the great point.

22324. Another interest which attaches to the experiment that you are about to try is that the material is spherical ?—That is so.

22325. It is in balls ?—That is so.

22326. About what size ?—Two inches.

22327. And what is the advantage that you see in the use of spherical material in regard to the air spaces ?— I foresee that we shall have an amount of internal surface in the filter, larger than if we used an irregular surface, like broken clinker ; and air spaces.

22328. And the air space ; if the form of each piece of the material is the same the air spaces will also be alike ? —Yes.

22329. And all equally large ?—Yes.

22330. In reply to Question 22038 you give some interesting tables—the result of treating precipitated storm waters upon percolating filters of different depth, but when you put partially settled storm waters or unsettled storm waters upon the percolation beds the results were more or less unsatisfactory, because the suspended matter coming out had not remained long enough in the filter, had it ?—That is so. The matter washed out from a filter treating screened storm water and was putrescent in character.

22331. Dr. Stafford asked you something about the washing out of nitrates from percolating filters at times of storm : if much suspended matter is brought to the filter in times of storm there would be almost a complete disappearance of nitrates very soon, would there not ?— I have never found them disappear in storm water effluent.

22332. Not entirely, but they have been greatly reduced ?—Greatly reduced.

22333. And much more reduced where you have suspended matter ?—Yes.

22334. There is an interesting feature in these tables which I would like to call attention to, and that is this : For instance, if Table IV (c) is looked at, it will be seen that the filtrate from the precipitation bed, including, I take it, the suspended matter coming out with it, only takes up 13 per cent. of the dissolved oxygen ?—Yes, that is so.

22335. That would be, of course, after 24 hours and after saturation ?—Stand 24 hours in a laboratory.

22336. And that is a very small proportion ?—Yes it is a very low figure for an average.

22337. With a 6-feet bed, working at 100 gallons per square yard, I see the result only took up 10 per cent. of dissolved oxygen ?—I have had particular filtrates that have taken up none.

22338. Then one of the features of the percolating bed filtration at Leeds was the great amount of dissolved oxygen contained in the filtrate itself without adding any ?—In a continuous filter effluent ?

22339. Yes.—Yes ; they are usually saturated.

22340. Almost saturated ?—Yes, contact bed effluents are rather under saturation point.

22341. That is a distinct advantage ?—That is a general rule.

22342. In Question 22027 you refer to the effects of intermittence of flow upon percolating filters. You are asked whether the feed of a percolating filter should be intermittent or continuous, and you suggest that it should, if possible, be continuous, as any intermittency tends to produce a filtrate fluctuating in quality. The expression of that opinion must be based, is it not, upon the particular kind of sprinklers you have been using at Leeds ?—Certainly ; I do not speak with regard to any other sprinklers.

22343. You have been using sprinklers which work intermittently, and I think you said to Sir William Ramsay, or someone, that when they started and stopped there was irregularity of distribution ?—Yes.

22344. But if you had upon very large rectangular filters, a distribution, a continuous flow, which passed along the surface of the filter from end to end, and then returned, you would get intermittency without irregularity, would you not. If you have no experience, do not attempt to reply ?—I could not say.

22345. You do not mean, do you, that intermittence *per se* is a bad thing ?—No.

22346. On the contrary, perhaps, have you not found certain advantages in intermittence ?—Yes ; the objection is that the arm is delivering sewage at a fixed place until it gains momentum to move round.

22347. It is simply the fact of your own sprinklers having been more or less unsatisfactory ?—That is so.

22348. That leads you to say that it is desirable, as far as possible, to have a continuous flow ?—Yes.

22349. But assuming the continuous flow would not be open to the disadvantage you refer to, the intermittence has a certain advantage, has it not ?—Yes.

22350. In regard to the growths ?—Yes, we find with the intermittence they are not so thick.

22351. You find that by intermitting the flow a few minutes each time, the growth on the surface is reduced ? —Yes.

22352. On the other hand, the intermittence with very coarse percolating filters is a very great disadvantage ?— Yes, you get intermittency in the effluent then.

22353. In a percolating filter where you have intermittence on the surface, intermittence of flow, possibly working for one minute and then standing for three minutes ; does that appear much in the outflow at the bottom, or is there a gradual equalisation of the outflow at the bottom ?—With coarse material you can see a fluctuation in the amount coming out.

22354. But it is not a very great fluctuation even with coarse material?—No. If you have fine material of course you see no difference in the rate of flow from the bed.

22355. What is the speed of passage through a coarse percolating filter 9 feet deep?—If dye such as fluorescein is put in the sewage going on to the filter, it will appear in the filtrate within two minutes if the bed is made of coarse material.

22356. That is, discolouration appears?—Yes.

22357. So that the action of percolating filters on dissolved impurities is marvellously rapid?—Yes.

22358. On the other hand the action upon suspended matters going through the filters is very much more slow, is it not?—I should judge it would take the solids about a month to pass through an ordinary coarse filter.

22359. That is the reason why probably you think storm waters ought not to be left really on filters of that kind, if they bring to the filter much suspended matter, because they wash it through much too fast?—They wash it through much too fast, but if there is an efficient straining filter after such a filter, I do not see that there is any disadvantage.

22360. Provided you have a subsequent process?—Yes.

22361. Then briefly, in regard to both kinds of filtration, it appears very important, provided there is a local opportunity of dealing with the sludge, to settle solids out as much as possible?—For reasons of purification.

22362. In either case?—Yes.

22363. And for other reasons surely; the life of the contact beds for instance?—Even with contact beds treating a very small amount of suspended matter down to 8 grains per gallon, I have still had a remarkable rate of clogging occurring.

22364. Yes, but I think you have told us also that much of that was due to disintegration and consolidation?—Yes, consolidation, but I have had it occur also in the case of the small Cameron plant.

22365. But the quantity of suspended matter going on in those cases is considerable?—It is about thirteen on the average.

22366. But supposing you put clarified effluent on contact beds, is the life of the bed likely to be considerable?—Yes, much more than solid matter.

22367. In regard to contact beds, the question is this, sooner of later you are bound to reach a condition when you will have to wash or renew the material?—Yes.

22368. But if you put on the contact beds effluents which do not contain much suspended matter, they may last for many years?—I see no reason why they should not.

22369. Putting crude sewage on beds you find a primary bed absolutely choked in two years?—Yes.

22370. You have formed the opinion that the cost of renewing the material, or washing the material, would not be a prohibitive one, have you?—I could not answer that; it depends on the financial state of the town.

22371. It is a question of engineering whether it is cheaper to have a large tank area and to spend money on chemical precipitants, to press sludge and deal with a large quantity of sludge, or whether it is cheaper to deal with a large part of the suspended matter on the filter, and wash out or renew the material more often?—I think it is a question as to whether the corporation or municipality will rather face a large annual cost or a great capital cost.

22372. It is a question largely of finance?—Yes.

22373. (*Sir William Ramsay.*) I want to refer to your answer to Question 22024 where you speak of the depths of the filter. We have heard about that already; I want to ask, would it come to the same thing if you had a shallower filter at a slower rate? This is important as a question of levels; in many works it would be impossible to make a 9 feet or 10 feet filter. Would it be possible to have a 5 feet filter, making the sewage pass over at half the rate?—Yes, I think the rate of flow on to a filter does make some difference. In my answers to certain questions you will find that.

22374. But not to that particular one, I think?—In 22038, Tables IV. (*a*) and (*c*) show the results obtained from the same filter, six feet deep, and treating sewage at the rate of 100 gallons per square yard. Recently it has been treating 200 gallons per square yard; there is a slight difference in the result obtained.

22375. Would it compensate for want of depth—you see the importance of it from the point of view of pumping?—Yes.

22376. Is it possible to overcome this difficulty where pumping is not admissible, in a small sewage work for example, by increasing the area of the filter and lessening the rate?—With regard to liquid containing a small amount of suspended matter, I think that would answer, but I should not like to give any opinion with regard to a filter treating crude sewage. I do not think there that you could get a good effluent with much under 7 or 8 feet even with a very reduced flow.

22377. (*Colonel Harding.*) But if in a certain situation it were not possible to get percolating filters beyond a given depth, the circumstances might be made to fit that depth by reducing the suspended matter going on to the filters?—Certainly.

22378. That would be the best way of meeting it; instead of reducing the flow you would reduce the suspended matter?—That is so.

22379—80. Then a filter of reduced depth would give adequate results?—Yes.

LEEDS.

Appendix to Evidence of Mr. W. H. Harrison.

Tables showing average analyses of sewage, tank liquor, and filter effluents at Leeds, January, 1903—December, 1904.

PROCESSES OF TREATMENT:

(*a*) Chemical Precipitation.

(*b*) Open Septic Tanks and Double Contact Beds.

(*c*) Exeter Septic Tank and Single Contact Beds.

(*d*) Continuous Filtration, viz.:—

Leeds Filter.

Whittaker Filter.

Ducat Filter.

January, 1903.

LEEDS.

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·93	3·53	2·53
Albuminoid nitrogen	·617	1·18	·840
Oxygen absorbed from $KMnO_4$ in 4 hours	7·79	8·24	9·79
Suspended solids	—	—	47.7
Soluble solids	—	—	101·3

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 400¾ million gallons.
Amount of lime used during the month - 68 tons 9 cwts.
Amount of sludge dealt with during the month - 8,152 tons.
Amount of sludge removed from the works - 275 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·56	1·90	1·80
Albuminoid nitrogen	·345	·444	·367
Oxygen absorbed from $KMnO_4$ in 4 hours	3·72	6·67	4·48
Suspended solids	—	—	19·0
Soluble solids	—	—	112·1

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hour flow.
Amount of septic sludge removed during the month - 2,346 tons.
Amount of sewage treated by the septic tanks - 67,410,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·857	1·09	·953
Albuminoid nitrogen	·188	·410	.264
Oxygen absorbed from $KMnO_4$ in 4 hours	1·90	3·74	3·12
Suspended solids	—	—	10·5
Soluble solids	—	—	89·5

Number of samples analysed for the average = 4.

Number of times primary bed was filled during month - 33.
Number of times secondary bed was filled during month - 33.
Amount of tank liquor treated per cube yard per 24 hours - 30·76 gallons.
Amount of tank liquor treated during the month - 2,111,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·264	·260	·260
Albuminoid nitrogen	·041	·076	·054
Nitric nitrogen	1·90	2·45	2·40
Oxygen absorbed from $KMnO_4$ in 4 hours	·202	·531	·395
Dissolved oxygen taken up in 24 hours	—	33%	16%
Incubator test { Before	·10	·32	·185
Incubator test { After	·21	·20	·171
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of sludge removed during the month - nil.
Amount of sewage treated by the process - 583,609 gallons.

Average analysis of tank liquor—

Ammoniacal nitrogen	1·20
Albuminoid nitrogen	·350
Oxygen absorbed from $KMnO_4$ in 4 hours	2·85
Suspended solids	14·1
Soluble solids	88·5

Number of samples analysed for the average = 1.

Number of times beds were filled during the month - 193
Amount of tank liquor treated per cube yard per 24 hours - 45 gallons.

Average analysis of final effluent—

Ammoniacal nitrogen	·419
Albuminoid nitrogen	·128
Nitric nitrogen	1·47
Oxygen absorbed from $KMnO_4$ in 4 hours	·88
Dissolved oxygen taken up in 24 hours	83%
Incubator test { Before	·21
Incubator test { After	·10
Suspended solids	2·85

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	39 Gallons.		49 Gallons.		46 Gallons.	
	Crude.	Sand Filtered.	Crude.	Sand Filtered.	Crude.	Settled.
Ammoniacal nitrogen	·431	·502	·429	·535	·448	·442
Albuminoid nitrogen	·264	·131	·101	·091	·128	·130
Nitric nitrogen	·08	·564	1·47	·800	—	1·51
Oxygen absorbed from $KMnO_4$ in 4 hours	2·77	·927	1·28	·69	1·42	·542
Dissolved oxygen taken up in 24 hours	54%	55%	15%	29%	58%	—
Incubator test { Before	·90	·26	·36	·22	—	·40
Incubator test { After	1·14	·21	·00	·21	—	·40
Suspended solids	19·7	3·7	8·9	hy. tr.	5·1	hy. tr.
Number of samples analysed for the average	1	4	1	4	1	1

June 18th, 1903. *W. H. Harrison.*

LEEDS—*continued.*

February, 1903.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·63	1·51	1·56
Albuminoid nitrogen	·458	1·09	·621
Oxygen absorbed from $KMnO_4$ in 4 hours	13·3	12·6	10·0
Suspended solids	—	—	66·7
Soluble solids	—	—	127·1

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - - - - - - - 375,000,000 gallons.

Amount of lime used during the month - - - - - - - 58 tons 11 cwts.

Amount of sludge dealt with during the month - - - - - - 8,555 tons.

Amount of sludge removed from the works - - - - - - - 222 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·54	1·69	1·65
Albuminoid nitrogen	·260	·383	·367
Oxygen absorbed from $KMnO_4$ in 4 hours	4·60	9·00	5·32
Suspended solids	—	—	16·7
Soluble solids	—	—	119·2

Number of samples analysed for the average = 4.

OPEN SEPTIC TANK AND DOUBLE CONTRACT PROCESS—

Average daily flow through the tanks - - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - - nil.

Amount of sewage treated by the septic tanks - - - - - - 60,770,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·852	1·18	1·04
Albuminoid nitrogen	·460	·617	·563
Oxygen absorbed from $KMnO_4$ in 4 hours	6·97	9·62	7·27
Suspended solids	—	—	17·8
Soluble solids	—	—	104·1

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - - - - - 33.

Number of times secondary bed was filled during month - - - - 33.

Amount of tank liquor treated per cube yard per 24 hours - - - - 34·04 gallons.

Amount of tank liquor treated during the month - - - - - - 2,111,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·200	·339	·233
Albuminoid nitrogen	·041	·094	·078
Nitric nitrogen	2·00	3·07	2·42
Oxygen absorbed from $KMnO_4$ in 4 hours	·800	·728	·700
Dissolved oxygen taken up in 24 hours	20%	30%	22%
Incubator test — Before	·07	·22	·14
Incubator test — After	·12	·42	·20
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of sludge removed during the month - nil.
Amount of sewage treated by the process - 516,132 gallons.
Average analysis of tank liquor—
Ammoniacal nitrogen - 1·07
Albuminoid nitrogen - ·494
Oxygen absorbed from $KMnO_4$ in 4 hours - 4·88
Suspended solids - 12·8
Soluble solids - 83·2
Number of samples analysed for the average = 1.

Number of times beds were filled during the month - 177
Amount of tank liquor treated per cube yard per 24 hours - 44 gallons.
Average analysis of final effluent—
Ammoniacal nitrogen - ·537
Albuminoid nitrogen - ·247
Nitric nitrogen - 1·70
Oxygen absorbed from $KMnO_4$ in 4 hours - 1·13
Dissolved oxygen taken up in 24 hours - 66%
Incubator test — Before - ·40
Incubator test — After - ·37
Suspended solids - 1·71
Number of samples analysed for the average = 1.

CONTINUOUS PROCESS—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	40 gallons.		49 gallons.		47 gallons.	
	Crude.	Sand Filtered.	Crude.	Sand Filtered.	Crude.	Settled.
Ammoniacal nitrogen	·515	·477	·588	·406	·561	·494
Albuminoid nitrogen	·339	·172	·182	·115	·161	·131
Nitric nitrogen	hy. tr.	·52	·54	1·06	1·81	1·81
Oxygen absorbed from $KMnO_4$ in 4 hours	4·72	2·02	2·31	·647	·963	·444
Dissolved oxygen taken up in 24 hours	100%	43%	75%	34%	58%	—
Incubator test — Before	1·39	·60	·72	·19	3·0	·10
Incubator test — After	3·24	·94	·80	·27	3·8	·24
Suspended solids	28·7	4·0	10·4	1·4	6·1	—
Number of samples analysed for the average	1	3	1	4	1	1

June 18th, 1903. *W. H. Harrison.*

LEEDS—*continued.*

March. 1903.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·76	1·69	1·82
Albuminoid nitrogen	·433	·593	·506
Oxygen absorbed from $KMnO_4$ in 4 hours	5·81	10·10	9·09
Suspended solids	—	—	48·4
Soluble solids	—	—	94·0

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - - - - - - 386½ million gallons.

Amount of lime used during the month - - - - - - 64 tons 16 cwts.

Amount of sludge dealt with during the month - - - - - 9,070 tons.

Amount of sludge removed from the works - - - - - 368 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·31	1·81	1·49
Albuminoid nitrogen	·209	·345	·274
Oxygen absorbed from $KMnO_4$ in 4 hours	2·08	4·75	3·60
Suspended solids	—	—	9·4
Soluble solids	—	—	92·5

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - nil.

Amount of sewage treated by the septic tanks - - - - - 63,430,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·01	1·23	1·14
Albuminoid nitrogen	·311	·549	·422
Oxygen absorbed from $KMnO_4$ in 4 hours	3·30	6·04	5·54
Suspended solids	—	—	20·8
Soluble solids	—	—	89·8

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - - - - 43.

Number of times secondary bed was filled during month - - - 43.

Amount of tank liquor treated per cube yard per 24 hours - - 36·86 gallons.

Amount of tank liquor treated during the month - - - - - 2,668,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·155	·153	·168
Albuminoid nitrogen	·051	·056	·054
Nitric nitrogen	2·54	1·80	2·11
Oxygen absorbed from $KMnO_4$ in 4 hours	·477	·645	·54
Dissolved oxygen taken up in 24 hours	20%	20%	24%
Incubator test — Before	·11	·22	·12
Incubator test — After	·17	·20	·19
Suspended solids	—	—	2·5

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of sludge removed during the month - none.
Amount of sewage treated by the process - 440,000 gallons.

Average analysis of tank liquor—

Ammoniacal nitrogen	1·17
Albuminoid nitrogen	·182
Oxygen absorbed from $KMnO_4$ in 4 hours	2·41
Suspended solids	11·5
Soluble solids	83·5

Number of samples analysed for the average = 1.

Number of times beds were filled during the month - 184
Amount of tank liquor treated per cube yard per 24 hours - 34
Average analysis of final effluent—

Ammoniacal nitrogen	·294
Albuminoid nitrogen	·094
Nitric nitrogen	1·90
Oxygen absorbed from $KMnO_4$ in 4 hours	·89
Dissolved oxygen taken up in 24 hours	28%
Incubator test — Before	·30
Incubator test — After	·37
Suspended solids	4·0

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	37 gallons.		47 gallons.		44 gallons.	
	Unsettled.	Sand Filtered.	Unsettled.	Sand Filtered.	Unsettled.	Settled.
Ammoniacal nitrogen	·301	·130	·266	·345	·398	·291
Albuminoid nitrogen	·110	·027	·094	·069	·068	·036
Nitric nitrogen	1·18	1·80	1·92	1·33	2·00	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·6	·48	·85	·474	·67	·33
Dissolved oxygen taken up in 24 hours	20%	5%	24%	15%	28%	—
Incubator test — Before	·56	·18	·25	·13	·20	·07
Incubator test — After	·58	·14	·28	·14	·25	·11
Suspended solids	7·1	tr.	9·5	2·8	1·9	tr.
Number of samples analysed for the average	1	1	1	4	1	1

REMARKS.—The analyses for the Leeds Filter were made after the bed had been resting one month and the surface placed.

June 30th, 1903.

W. H. Harrison.

LEEDS—*continued.*

April, 1903.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·16	2·21	2·11
Albuminoid nitrogen	·617	·741	·679
Oxygen absorbed from $KMnO_4$ in 4 hours	9·71	13·6	11·8
Suspended solids	--	--	41·7
Soluble solids	--	--	109·0

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - - - - - - 482,000,000 gallons.

Amount of lime used during the month - - - - - - - 67 tons 10 cwts.

Amount of sludge dealt with during the month - - - - - - 9,526 tons.

Amount of sludge removed from the works - - - - - - - 95 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·54	2·28	1·99
Albuminoid nitrogen	·316	·345	·329
Oxygen absorbed from $KMnO_4$ in 4 hours	3·10	7·22	4·32
Suspended solids	--	--	10·4
Soluble solids	--	--	88·8

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - - nil.

Amount of sewage treated by the septic tanks - - - - - - 79,520,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·09	1·27	1·13
Albuminoid nitrogen	·332	·616	·499
Oxygen absorbed from $KMnO_4$ in 4 hours	3·81	7·41	7·9
Suspended solids	10·8	5·5	9·1
Soluble solids	95·1	106·4	98·6

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - - - - 45.

Number of times secondary bed was filled during month - - - - 45.

Amount of tank liquor treated per cube yard per 24 hours - - - - 42·02 gallons.

Amount of tank liquor treated during the month - - - - - 2,791,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·222	·419	·325
Albuminoid nitrogen	·049	·103	·072
Nitric nitrogen	1·30	1·90	1·82
Oxygen absorbed from $KMnO_4$ in 4 hours	·477	·945	·774
Dissolved oxygen taken up in 24 hours	20%	16%	29%
Incubator test — Before	·16	·31	·18
Incubator test — After	·32	·35	·33
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours.
Amount of sludge removed during the month	none.
Amount of sewage treated by the process	662,824 gallons

Average analysis of tank liquor—

Ammoniacal nitrogen	1·58
Albuminoid nitrogen	·208
Oxygen absorbed from $KMnO_4$ in 4 hours	4·32
Suspended solids	12·1
Soluble solids	84·2

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	232
Amount of tank liquor treated per cube yard per 24 hours	53 gallons.

Average analysis of final effluent—

Ammoniacal nitrogen	·602
Albuminoid nitrogen	·128
Nitric nitrogen	·980
Oxygen absorbed from $KMnO_4$ in 4 hours	·950
Dissolved oxygen taken up in 24 hours	28%
Incubator test — Before	·32
Incubator test — After	·38
Suspended solids	8·0

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	48 gallons.		61 gallons.		58 gallons.	
	Unsettled.	Sand Filtered.	Unsettled.	Sand Filtered.	Unsettled.	Settled.
Ammoniacal nitrogen	·294	·316	·603	·603	·369	·345
Albuminoid nitrogen	·098	·058	·161	·141	·078	·047
Nitric nitrogen	·600	·770	·88	1·09	—	1·40
Oxygen absorbed from $KMnO_4$ in 4 hours	1·51	·712	1·51	·94	·808	·525
Dissolved oxygen taken up in 24 hours	44%	16%	28%	26%	28%	—
Incubator test — Before	·46	·19	·67	·49	·20	·14
Incubator test — After	·66	·20	·62	·50	·30	·17
Suspended solids	10·0	2·2	8·7	hy. tr.	2·8	—
Number of samples analysed for the average	1	4	1	4	1	1

July 3rd, 1903. *W. H. Harrison.*

May, 1903.

LEEDS—*continued.*

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·12	2·42	1·68
Albuminoid nitrogen	·494	·839	·538
Oxygen absorbed from $KMnO_4$ in 4 hours	3·06	14·52	9·52
Suspended solids	—	—	40·2
Soluble solids	—	—	106·7

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS.

Amount of sewage treated during the month — 454,000,000 gallons.

Amount of lime used during the month — 72 tons 7 cwt.

Amount of sludge dealt with during the month — 9,076 tons.

Amount of sludge removed from the works — 277 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·79	2·01	1·61
Albuminoid nitrogen	·247	·433	·376
Oxygen absorbed from $KMnO_4$ in 4 hours	3·80	6·15	4·67
Suspended solids	—	—	6·4
Soluble solids	—	—	104·0

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks — 24 hours' flow.

Amount of septic sludge removed during the month — nil.

Amount of sewage treated by the process — 71,340,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·951	1·41	1·10
Albuminoid nitrogen	·311	·445	·373
Oxygen absorbed from $KMnO_4$ in 4 hours	4·75	6·95	5·95
Suspended solids	14·8	18·4	13·1
Soluble solids	91·7	92·8	95·1

Number of samples analysed for the average = 4.

Number of times primary bed was filled during month — 39.

Number of times secondary bed was filled during month — 39.

Amount of tank liquor treated per cube yard per 24 hours — 34·12 gallons.

Amount of tank liquor treated during the month — 2,343,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average
Ammoniacal nitrogen	·083	·345	·244
Albuminoid nitrogen	·058	·090	·065
Nitric nitrogen	1·94	3·00	2·05
Oxygen absorbed from $KMnO_4$ in 4 hours	·040	·904	·591
Dissolved oxygen taken up in 24 hours	16%	50%	42%
Incubator test — Before	·22	·32	·28
Incubator test — After	·31	·45	·26
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours.
Amount of sludge removed during the month	nil.
Amount of sewage treated by the process	563,100 gallons
Average analysis of tank liquor—	
Ammoniacal nitrogen	·950
Albuminoid nitrogen	·302
Oxygen absorbed from $KMnO_4$ in 4 hours	6·68
Suspended solids	16·5
Soluble solids	93·7

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	208
Amount of tank liquor treated per cube yard per 24 hours	44 gallons.
Average analysis of final effluent—	
Ammoniacal nitrogen	·448
Albuminoid nitrogen	·153
Nitric nitrogen	1·20
Oxygen absorbed from $KMnO_4$ in 4 hours	1·64
Dissolved oxygen taken up in 24 hours	75%
Incubator test — Before	·6
Incubator test — After	·6
Suspended solids	8·6

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	42 gallons.		53 gallons.		50 gallons.	
	Unsettled.	Sand Filtered.	Unsettled.	Sand Filtered.	Unsettled.	Settled.
Ammoniacal nitrogen	·617	·221	·419	·515	·433	·419
Albuminoid nitrogen	·101	·037	·173	·104	·121	·078
Nitric nitrogen	·78	1·15	·94	·99	1·71	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·60	·585	1·82	1·10	1·19	·660
Dissolved oxygen taken up in 24 hours	36%	24%	20%	35%	33%	—
Incubator test — Before	·62	·19	·86	·34	·38	·19
Incubator test — After	·62	·19	·77	·42	·42	·21
Suspended solids	10·2	Hy. Tr.	10·7	5·4	1·0	Tr.
Number of samples analysed for the average	1	4	1	4	1	1

July 7th, 1903. *W. H. Harrison.*

June, 1903.

LEEDS—*continued.*

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·33	2·24	2·15
Albuminoid nitrogen	·445	·681	·606
Oxygen absorbed from $KMnO_4$ in 4 hours	15·4	12·6	14·2
Suspended solids	—	—	56·4
Soluble solids	—	—	125·4

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month	470,000,000 gallons.
Amount of lime used during the month	73 tons 3 cwt.
Amount of sludge dealt with during the month	10,088 tons.
Amount of sludge removed from the works	215 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·93	2·24	1·97
Albuminoid nitrogen	·321	·483	·352
Oxygen absorbed from $KMnO_4$ in 4 hours	4·8	8·0	5·4
Suspended solids	—	—	10·0
Soluble solids	—	—	110·2

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks	24 hours' flow.
Amount of septic sludge removed during the month	nil.
Amount of sewage treated by the process	77,825,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·866	1·15	·971
Albuminoid nitrogen	·395	·411	·388
Oxygen absorbed from $KMnO_4$ in 4 hours	7·35	7·84	7·8
Suspended solids	18·0	16·7	18·4
Soluble solids	97·8	81·1	97·4

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month	45
Number of times secondary bed was filled during month	45
Amount of tank liquor treated per cube yard per 24 hours	40·6 gallons.
Amount of tank liquor treated during the month	2,700,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·220	·329	·265
Albuminoid nitrogen	·029	·056	·048
Nitric nitrogen	1·44	1·41	1·35
Oxygen absorbed from $KMnO_4$ in 4 hours	·68	·987	·844
Dissolved oxygen taken up in 24 hours	34%	33%	27%
Incubator test — Before	·24	·32	·27
Incubator test — After	·25	·39	·30
Suspended solids	—	—	2·7

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours' flow.
Amount of sludge removed during the month	nil.
Amount of sewage treated by the process	592,000 gallons.
Average analysis of tank liquor—	
Ammoniacal nitrogen	1·34
Albuminoid nitrogen	·440
Oxygen absorbed from $KMnO_4$ in 4 hours	5.97
Suspended solids	12·1
Soluble solids	69·2

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	256
Amount of tank liquor treated per cube yard per 24 hours	47 gallons.
Average analysis of final effluent—	
Ammoniacal nitrogen	·494
Albuminoid nitrogen	·108
Nitric nitrogen	1·10
Oxygen absorbed from $KMnO_4$ in 4 hours	1·06
Dissolved oxygen taken up in 24 hours	33%
Incubator test — Before	·34
Incubator test — After	·34
Suspended solids	10·1

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	47 gallons.		59·6 Gallons.		50·6 gallons.	
	Unsettled.	Sand Filtered.	Unsettled.	Sand Filtered.	Unsettled.	Settled.
Ammoniacal nitrogen	·588	·487	·797	·597	·634	·528
Albuminoid nitrogen	·300	·102	·262	·115	·217	·124
Nitric nitrogen	·32	·314	·861	·597	—	·64
Oxygen absorbed from $KMnO_4$ in 4 hours	4·32	1·22	3·11	1·13	3·24	1·60
Dissolved oxygen taken up in 24 hours	100%	28%	41%	20%	53%	50%
Incubator test — Before	1·42	·46	·98	·39	1·03	·59
Incubator test — After	2·80	·41	1·03	·42	1·08	·47
Suspended solids	14·1	3·8	16·4	4·2	6·7	—
Number of samples analysed for the average	1	3	1	4	1	1

REMARKS.—The Ducat Bed was stopped on June 27th for a months' rest, owing to surface clogging.

July 23rd, 1903. *W. H. Harrison.*

LEEDS—*continued.*

July, 1903.

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·73	2·61	1·95
Albuminoid nitrogen	·382	·469	·465
Oxygen absorbed from $KMnO_4$ in 4 hours	15·5	15·9	14·2
Suspended solids	—	—	79·5
Soluble solids	—	—	95·0

Number of samples for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - - - - - - - 478¾ million gallons.

Amount of lime used during the month - - - - - - - - 79 tons 19 cwts.

Amount of sludge dealt with during the month - - - - - - 10,575 tons.

Amount of sludge removed from the works - - - - - - 136 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·49	1·39	1·64
Albuminoid nitrogen	·185	·222	·222
Oxygen absorbed from $KMnO_4$ in 4 hours	4·07	4·40	4·41
Suspended solids	—	—	8·0
Soluble solids	—	—	92·1

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - - - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - - none.

Amount of sewage treated by the septic tank - - - - - - 77¼ million gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·914	1·03	·963
Albuminoid nitrogen	·261	·291	·275
Oxygen absorbed from $KMnO_4$ in 4 hours	8·67	9·40	8·32
Suspended solids	17·7	20·4	18·7
Soluble solids	92·8	98·4	92·5

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - - - - 43.

Number of times secondary bed was filled during month - - - - 43.

Amount of tank liquor treated per cube yard per 24 hours - - - - 37·64 gallons.

Amount of tank liquor treated during the month - - - - - 2,583,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·601	·265	·347
Albuminoid nitrogen	·036	·063	·051
Nitric nitrogen	1·61	1·64	1·65
Oxygen absorbed from $KMnO_4$ in 4 hours	·777	·757	·932
Dissolved oxygen taken up in 24 hours	16%	33%	26%
Incubator test — Before	·277	·255	·322
Incubator test — After	·301	·480	·408
Suspended solids	—	—	2·0

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - - - - - - - 24 hours' flow.
Amount of sludge removed during the month - - - - - - none.
Amount of sewage treated by the process - - - - - - 678,300 gallons.
Average analysis of tank liquor—
Ammoniacal nitrogen - - - - - - - - - 1·27
Albuminoid nitrogen - - - - - - - - - ·641
Oxygen absorbed from $KMnO_4$ in 4 hours - - - - - 6·84
Suspended solids - - - - - - - - - - 16·4
Soluble solids - - - - - - - - - - 85·5

Number of samples analysed for the average = 1.

Number of times beds were filled during the month - - - - 252
Amount of tank liquor treated per cube yard per 24 hours - - - 54 gallons.
Average analysis of final effluent—
Ammoniacal nitrogen - - - - - - - - - ·484
Albuminoid nitrogen - - - - - - - - - ·071
Nitric nitrogen - - - - - - - - - - ·860
Oxygen absorbed from $KMnO_4$ in 4 hours - - - - - 1·70
Dissolved oxygen taken up in 24 hours - - - - - 33%
Incubator test — Before - - - - - - - - - ·688
Incubator test — After - - - - - - - - - ·710
Suspended solids - - - - - - - - - - 6·4

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

	Leeds Filter.		Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	45 gallons		57 gallons.		—
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	——
Ammoniacal nitrogen	·649	·494	·441	·449	
Albuminoid nitrogen	·398	·128	·204	·091	
Nitric nitrogen	hy. tr.	·294	·640	·764	
Oxygen absorbed from $KMnO_4$ in 4 hours	5·9	1·57	3·47	·123	
Dissolved oxygen taken up in 24 hours	100%	56%	60%	26%	Bed Resting.
Incubator test — Before	3·0	·44	1·21	·50	
Incubator test — After	5·58	·80	1·37	·52	
Suspended solids	22·6	5·0	19·4	6·5	
Number of samples analysed for the average	1	4	1	4	

May 6th, 1904. *W. H. Harrison.*

LEEDS—*continued.* August, 1903.

SEWAGE— *Average Analysis of Sewage.*

———	Best.	Worst.	Average.
Ammoniacal nitrogen	1·67	2·16	2·14
Albuminoid nitrogen	·433	·988	·766
Oxygen absorbed from $KMnO_4$ in 4 hours	10·9	15·5	13·2
Suspended solids	—	—	70·2
Soluble solids	—	—	99·7

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - - - - - - 479 million gallons.

Amount of lime used during the month - - - - - - - 75 tons 3 cwts.

Amount of sludge dealt with during the month - - - - - 7,119 tons.

Amount of sludge removed from the works - - - - - - 344 tons.

Average Analysis of Tank Liquor

———	Best.	Worst.	Average.
Ammoniacal nitrogen	2·09	2·42	1·93
Albuminoid nitrogen	·260	·593	·399
Oxygen absorbed from $KMnO_4$ in 4 hours	5·17	6·71	5·22
Suspended solids	—	—	8·4
Soluble solids	—	—	105·4

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - none.

Amount of sewage treated by the process - - - - - - 81⅓ million gallons

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·883	1·82	1·27
Albuminoid nitrogen	·355	·386	·354
Oxygen absorbed from $KMnO_4$ in 4 hours	5·75	8·14	6·90
Suspended solids	17·1	—	17·5
Soluble solids	79·1	—	82·4

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - - - - 44

Number of times secondary bed was filled during month - - - - 44

Amount of tank liquor treated per cube yard per 24 hours - - - - 38·4 gallons.

Amount of tank liquor treated during the month - - - - - - 2,644,000 gallons.

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·184	·213	·183
Albuminoid nitrogen	·043	·063	·043
Nitric nitrogen	1·77	1·42	1·68
Oxygen absorbed from $KMnO_4$ in 4 hours	·471	·667	·602
Dissolved oxygen taken up in 24 hours	41%	36%	41%
Incubator test — Before	·18	·25	·21
Incubator test — After	·24	·58	·37
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours' flow.
Amount of sludge removed during the month	none.
Amount of sewage treated by the process	676,300 gallons.
Average analysis of tank liquor—	
Ammoniacal nitrogen	1·09
Albuminoid nitrogen	·271
Oxygen absorbed from $KMnO_4$ in 4 hours	7·05
Suspended solids	16·0
Soluble solids	70·8

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	266
Amount of tank liquor treated per cube yard per 24 hours	52 gallons.
Average Analysis of Final Effluent—	
Ammoniacal nitrogen	·494
Albuminoid nitrogen	·098
Nitric nitrogen	·540
Oxygen absorbed from $KMnO_4$ in 4 hours	1·78
Dissolved oxygen taken up in 24 hours	50%
Incubator test — Before	·71
Incubator test — After	·42
Suspended solids	8·4

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

———	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	47 gallons.		60 gallons.		57 gallons.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
Ammoniacal nitrogen	·494	·473	·485	·396	·425	·494
Albuminoid nitrogen	·247	·125	·157	·053	·081	·068
Nitric nitrogen	—	·130	·760	1·00	—	1·57
Oxygen absorbed from $KMnO_4$ in 4 hours	4·97	1·24	3·44	·824	1·02	·982
Dissolved oxygen taken up in 24 hours	100%	78%	58%	45%	50%	—
Incubator test — Before	1·5	.57	·11	·35	·30	·24
Incubator test — After	3·0	.67	·10	·34	·30	·21
Suspended solids	24·8	5·7	12·8	4·2	5·2	—
Number of samples analysed for the average	1	4	1	4	1	1

May 6th, 1904. *W. H. Harrison.*

LEEDS—*continued.*

SEWAGE— *Average Analysis of Sewage.* September, 1903.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·60	1·99	1·73
Albuminoid nitrogen	·469	·632	·499
Oxygen absorbed from $KMnO_4$ in 4 hours	8·24	13·6	10·6
Suspended solids	—	—	104·0
Soluble solids	—	—	107·0

Number of samples analysed for the average = 3.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 438 million gallons.
Amount of lime used during the month - 72 tons 8 cwts.
Amount of sludge dealt with during the month - 9,972 tons.
Amount of sludge removed from the works - 246 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·45	1·59	1·51
Albuminoid nitrogen	·222	·247	·247
Oxygen absorbed from $KMnO_4$ in 4 hours	3·24	5·52	3·87
Suspended solids	—	—	6·1
Soluble solids	—	—	90·0

Number of samples analysed for the average = 3.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 71,160,000 gallons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·932	1·12	·983
Albuminoid nitrogen	·227	·340	·274
Oxygen absorbed from $KMnO_4$ in 4 hours	4·04	6·24	5·40
Suspended solids	—	—	17·1
Soluble solids	—	—	83·5

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - 38
Number of times secondary bed was filled during month - 38
Amount of tank liquor treated per cube yard per 24 hours - 33·4 gallons.
Amount of tank liquor treated during month - 2,226,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·099	·124	·111
Albuminoid nitrogen	·027	·031	·029
Nitric nitrogen	1·51	2·60	2·05
Oxygen absorbed from $KMnO_4$ in 4 hours	·438	·385	·411
Dissolved oxygen taken up in 24 hours	16%	30%	23%
Incubator test — Before	·14	·17	·15
Incubator test — After	·14	.10	.14
Suspended solids	—	—	hy. tr.

Number of samples analysed for the average = 2.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours' flow.
Amount of sludge removed during the month	none.
Amount of sewage treated by the process	563,000 gallons.
Average analysis of tank liquor—	
Ammoniacal nitrogen	1·24
Albuminoid nitrogen	·238
Oxygen absorbed from $KMnO_4$ in 4 hours	3·25
Suspended solids	9·1
Soluble solids	81·1

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	232.
Amount of tank liquor treated per cube yard per 24 hours	45 gallons.
Average analysis of final effluent—	
Ammoniacal nitrogen	·588
Albuminoid nitrogen	·305
Nitric nitrogen	1·81
Oxygen absorbed from $KMnO_4$ in 4 hours	1·42
Dissolved oxygen taken up in 24 hours	50%
Incubator test — Before	1·08
Incubator test — After	·67
Suspended solids	16·2

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.	
Amount treated per cube yard per 24 hours	43 gallons.		54 gallons.		51 gallons.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
Ammoniacal nitrogen	·574	·516	·300	·183	·574	·457
Albuminoid nitrogen	·254	·101	·098	·039	·155	·058
Nitric nitrogen	·300	·240	1·12	1·20	1·42	1·42
Oxygen absorbed from $KMnO_4$ in 4 hours	2·77	·104	1·15	·710	·942	·438
Dissolved oxygen taken up in 24 hours	100%	58%	33%	23%	50%	—
Incubator test — Before	1·3	·40	·51	·24	·42	·12
Incubator test — After	1·6	·42	·58	·28	·37	·12
Suspended solids	24·4	3·1	10·4	6·3	10·2	—
Number of samples analysed for the average	1	3	1	3	1	1

May 6th, 1904. *W. H. Harrison.*

LEEDS—*continued.*

October, 1903

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·30	1·92	1·49
Albuminoid nitrogen	·271	·543	·387
Oxygen absorbed from $KMnO_4$ in 4 hours	4·21	11·1	7·58
Suspended solids	—	—	40·4
Soluble solids	—	—	68·8

Number of samples analysed for the average = 3.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 269 million gallons.

Amount of lime used during the month - 43 tons 9 cwts.

Amount of sludge dealt with during the month - 7,204 tons.

Amount of sludge removed from the works - 270 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average
Ammoniacal nitrogen	·494	1·67	1·11
Albuminoid nitrogen	·123	·148	·173
Oxygen absorbed from $KMnO_4$ in 4 hours	1·00	3·92	2·35
Suspended solids	—	—	12·0
Soluble solids	—	—	72·7

Number of samples analysed for the average = 3.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.

Amount of septic sludge removed during the month - None.

Amount of sewage treated by the process - 45,920,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·676	1·15	·913
Albuminoid nitrogen	·211	·378	·294
Oxygen absorbed from $KMnO_4$ in 4 hours	2·92	4·81	3·86
Suspended solids	11·8	21·7	18·7
Soluble solids	82·8	77·2	80·0

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 19.

Number of times secondary bed was filled during month - 19.

Amount of tank liquor treated per cube yard per 24 hours - 16·4 gallons.

Amount of tank liquor treated during the month - 1,128,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·085	·085	1·11
Albuminoid nitrogen	·020	·049	·02
Nitric nitrogen	3·22	2·44	2·68
Oxygen absorbed from $KMnO_4$ in 4 hours	·29	·352	·410
Dissolved oxygen taken up in 24 hours	—	3%	15%
Incubator test — Before	·0	·04	·12
Incubator test — After	·07	·22	·18
Suspended solids	—	—	hy. tr.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours' flow.
Amount of sludge removed during the month	None.
Amount of sewage treated by the process	396,700
Average analysis of tank liquor—	
Ammoniacal nitrogen	1·23
Albuminoid nitrogen	·395
Oxygen absorbed from $KMnO_4$ in 4 hours	4·74
Suspended solids	10.5
Soluble solids	79·0

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	171
Amount of tank liquor treated per cube yard per 24 hours	31 gallons.
Average analysis of final effluent—	
Ammoniacal nitrogen	·484
Albuminoid nitrogen	·111
Nitric nitrogen	·600
Oxygen absorbed from $KMnO_4$ in 4 hours	1·17
Dissolved oxygen taken up in 24 hours	46%
Incubator test — Before	·47
Incubator test — After	·35
Suspended solid	9·1

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.		Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	30 gallons.		38 gallons.		—
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	——
Ammoniacal nitrogen	·400	·440	·313	·164	
Albuminoid nitrogen	·363	·088	·136	·024	
Nitric nitrogen	nil.	·372	·126	1·34	
Oxygen absorbed from $KMnO_4$ in 4 hours	4.57	·851	1·64	·705	Experiment
Dissolved oxygen taken up in 24 hours	100%	28%	46%	16%	Discontinued
Incubator test — Before	2·1	·30	·67	·21	
Incubator test — After	4·4	·34	·57	·21	
Suspended solids	33·5	4·2	15·2	2·0	
Number of samples analysed for the average	1	3	1	3	

May 6th, 1904. *W. H. Harrison.*

LEEDS—*continued.*

November, 1903.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·47	2·38	1·73
Albuminoid nitrogen	·445	·632	·522
Oxygen absorbed from $KMnO_4$ in 4 hours	9·60	8 3	8·97
Suspended solids	—	—	65·7
Soluble solids	—	—	107·0

Number of samples analysed for the average = 4.

PRECIPITAT ON PROCESS—

Amount of sewage treated during the month - - - - - - 483¼ million gallons.

Amount of lime used during the month - - - - - - - - 73 tons 3 cwts.

Amount of sludge dealt with during the month - - - - - - 5,903 tons.

Amount of sludge removed from the works - - - - - - 116 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·10	2·06	1·54
Albuminoid nitrogen	·161	·230	·186
Oxygen absorbed from $KMnO_4$ in 4 hours	2·85	2·84	3·51
Suspended solids	—	—	4·7
Soluble solids	—	—	111·2

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - - None.

Amount of sewage treated by the process - - - - - - - 80,520,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	.772	1·36	1·0 2
Albuminoid nitrogen	·306	·494	·354
Oxygen absorbed from $KMnO_4$ in 4 hours	3·20	4·88	4·48
Suspended solids	9·8	15·0	13·4
Soluble solids	95·1	84·5	91·1

Number of samples analysed for the average = 3.

Number of times primary bed was filled during month - - - - - 42

Number of times secondary bed was filled during month - - - - 42

Amount of tank liquor treated per cube yard per 24 hours - - - - 35·4 gallons.

Amount of tank liquor treated during the month - - - - - - 2,358,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·071	·188	·115
Albuminoid nitrogen	·024	·041	·029
Nitric nitrogen	2·20	2·20	1·9
Oxygen absorbed from $KMnO_4$ in 4 hours	·338	·514	·417
Dissolved oxygen taken up in 24 hours	0%	0%	1·3%
Incubator test — Before	·07	·17	·11
Incubator test — After	·08	·20	·10
Suspended solids	—	—	Heavy Trace

Number of samples for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks — 24 hours' flow.
Amount of sludge removed during the month — None.
Amount of sewage treated by the process — 607,000 gallons.
Average analysis of tank liquor—
- Ammoniacal nitrogen — ·715
- Albuminoid nitrogen — ·141
- Oxygen absorbed from $KMnO_4$ in 4 hours — 2·31
- Suspended solids — 16·1
- Soluble solids — 81·8

Number of samples analysed for the average = 1.

Number of times beds were filled during the month — 263
Amount of tank liquor treated per cube yard per 24 hours — 48·9 gallons
Average analysis of final effluent—
- Ammoniacal nitrogen — ·247
- Albuminoid nitrogen — ·058
- Nitric nitrogen — ·660
- Oxygen absorbed from $KMnO_4$ in 4 hours — ·952
- Dissolved oxygen taken up in 24 hours — 3%
- Incubator test — Before — ·27
- Incubator test — After — ·17
- Suspended solids — 1·1

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

	Leeds Filter.		Whittaker Filter.	
Amount treated per cube yard per 24 hours	48 gallons.		61 gallons.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.
Ammoniacal nitrogen	·433	·469	·079	·128
Albuminoid nitrogen	·163	·088	·052	·034
Nitric nitrogen	·140	·185	·960	1·25
Oxygen absorbed from $KMnO_4$ in 4 hours	2·41	1·11	·971	·600
Dissolved oxygen taken up in 24 hours	51%	40%	8%	13%
Incubator test — Before	·97	·47	·31	·20
Incubator test — After	1·25	·52	·18	·24
Suspended solids	12·1	2·5	12·5	hy. tr.
Number of samples analysed for the average	1	4	1	4

May 6th, 1904. *W. H. Harrison.*

LEEDS—*continued.*

December, 1903.

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·33	1·74	1·83
Albuminoid nitrogen	·370	·457	·422
Oxygen absorbed from $KMnO_4$ in 4 hours	7·32	10·45	9·01
Suspended solids	—	—	41·4
Soluble solids	—	—	92·1

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - - - - - - 462¾ million gallons.

Amount of lime used during the month - - - - - - - 69 tons 2 cwts.

Amount of sludge dealt with during the month - - - - - 10,327 tons.

Amount of sludge removed from the works - - - - - - 156 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·71	·778	1·37
Albuminoid nitrogen	·123	·345	·194
Oxygen absorbed from $KMnO_4$ in 4 hours	4·34	7·34	5·35
Suspended solids	—	—	3.1
Soluble solids	—	—	98·0

Number of samples analysed for the average = 4.

OPEN SEPTIC TANKS AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - - - - - - - 24 hours' flow.

Amount of septic sludge removed during the month - - - - None.

Amount of sewage treated by the process - - - - - - 77,000,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average
Ammoniacal nitrogen	1·000	1·34	1·17
Albuminoid nitrogen	·251	·359	·305
Oxygen absorbed from $KMnO_4$ in 4 hours	4·31	5·80	5·05
Suspended solids	11·0	21·8	16·4
Soluble solids	86·4	82·8	84·6

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - - - - 42

Number of times secondary bed was filled during month - - - - 42

Amount of tank liquor treated per cube yard per 24 hours - - - 34·2 gallons.

Amount of tank liquor treated during the month - - - - - 2,358,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·178	·242	·169
Albuminoid nitrogen	·024	·036	·31
Nitric nitrogen	1·36	2·45	1·95
Oxygen absorbed from $KMnO_4$ in 4 hours	·597	·755	·612
Dissolved oxygen taken up in 24 hours	0%	0%	0%
Incubator test — After	·12	·15	·17
Incubator test — Before	·20	·24	·21
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 4.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - - - - - - - - 24 hours' flow
Amount of sludge removed during the month - - - - - - none.
Amount of sewage treated by the process - - - - - - - 590,000 gallons.
Average analysis of tank liquor—
Ammoniacal nitrogen - - - - - - - - - - ·882
Albuminoid nitrogen - - - - - - - - - - ·177
Oxygen absorbed from $KMnO_4$ in 4 hours - - - - - 3·15
Suspended solids - - - - - - - - - - - 10·4
Soluble solids - - - - - - - - - - - 84·4

Number of samples analysed for the average = 1.

Number of times beds were filled during the month - - - - - - 252
Amount of tank liquor treated per cube yard per 24 hours - - - - 47
Average analysis of final effluent—
Ammoniacal nitrogen - - - - - - - - - - ·357
Albuminoid nitrogen - - - - - - - - - - ·085
Nitric nitrogen - - - - - - - - - - - ·942
Oxygen absorbed from $KMnO_4$ in 4 hours - - - - - 1·20
Dissolved oxygen taken up in 24 hours - - - - - - 20%
Incubator test — Before - - - - - - - - - ·45
Incubator test — After - - - - - - - - - ·57
Suspended solids - - - - - - - - - - - 7·0

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

	Leeds Filter.		Whittake Filter.	
Amount treated per cube yard per 24 hours	46 gallons.		51 gallons.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.
Ammoniacal nitrogen	·418	·417	·182	·169
Albuminoid nitrogen	·231	·084	·088	·047
Nitric nitrogen	hy. tr.	·212	1·70	1·35
Oxygen absorbed from $KMnO_4$ in 4 hours	3·28	1·42	1·34	·865
Dissolved oxygen taken up in 24 hours	58%	48%	16%	15%
Incubator test — Before	1·22	·68	·47	·25
Incubator test — After	2·42	·74	·45	·34
Suspended solids	18·9	7·2	12·2	3·5
Number of samples analysed for the average	1	3	1	3

* May 6th, 1904.

W. H. Harrison.

January, 1904.

LEEDS - *continued.*

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·25	1·71	1·45
Albuminoid nitrogen	·358	·444	·438
Oxygen absorbed from $KMnO_4$ in 4 hours	9·14	13·1	9·61
Suspended solids	—	—	92·4
Soluble solids	—	—	93·8

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 441,750,000 gallons.
Amount of lime used during the month - 65 tons.
Amount of sludge dealt with during the month - 11,024 tons.
Amount of sludge removed from the works - 97 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·752	1·39	1·24
Albuminoid nitrogen	·161	·345	·250
Oxygen absorbed from $KMnO_4$ in 4 hours	5·24	4·11	4·64
Suspended solids	—	—	9·57
Soluble solids	—	—	93·1

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 76,175,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·931	1·02	·979
Albuminoid nitrogen	·232	·345	·289
Oxygen absorbed from $KMnO_4$ in 4 hours	5·82	4·52	5·17
Suspended solids	18·1	15·5	16·8
Soluble solids	88·8	81·5	85·1

Number of samples analysed for the average = 2 (average of several days).

Number of times primary bed was filled during month - 42.
Number of times secondary bed was filled during month - 42.
Amount of tank liquor treated per cube yard per 24 hours - 35·2 gallons.
Amount of tank liquor treated during the month - 2,237,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·192	·141	·215
Albuminoid nitrogen	·038	·058	·050
Nitric nitrogen	1·45	1·87	1·77
Oxygen absorbed from $KMnO_4$ in 4 hours	·410	·511	·545
Dissolved oxygen taken up in 24 hours	4 per cent.	35 per cent.	16 per cent.
Incubator test — Before	·082	·147	·134
Incubator test — After	·100	·200	·167
Suspended solids	—	—	Heavy Trace.

Number of samples analysed for the average=3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - 24 hours flow.
Amount of sludge removed during the month - none.
Amount of sewage treated by the process - 583,300 gallons.

Average analysis of tank liquor—

Ammoniacal nitrogen - 1·00
Albuminoid nitrogen - ·316
Oxygen absorbed from $KMnO_4$ in 4 hours - 3·61
Suspended solids - 10·1
Soluble solids - 75·5

Number of samples analysed for the average=1.

Number of times beds were filled during the month - 263
Amount of tank liquor treated per cube yard per 24 hours - 47·0

Average analysis of final effluent—

Ammoniacal nitrogen - 1·02
Albuminoid nitrogen - ·116
Nitric nitrogen - 1·06
Oxygen absorbed from $KMnO_4$ in 4 hours - 1·07
Dissolved oxygen taken up in 24 hours - 35 per cent.
Incubator test — Before - ·457
Incubator test — After - ·535
Suspended solids - 3·8

Number of samples analysed for the average=1.

CONTINUOUS PROCESSES—

	Leeds Filter.	Whittaker Filter.	Ducat Filter.
Amount treated per cube yard per 24 hours	—	—	—
Ammoniacal nitrogen	—	Resting.	Stopped.
Albuminoid nitrogen	—		
Nitric nitrogen	—		
Oxygen absorbed from $KMnO_4$ in 4 hours	—		
Dissolved oxygen taken up in 24 hours	—		
Incubator test	—		
Suspended solids	—		

Number of samples analysed for the average= .

LEEDS—*continued.*

February, 1904.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·25	1·32	1·28
Albuminoid nitrogen	·309	·469	·406
Oxygen absorbed from $KMnO_4$ in 4 hours	5·75	9·52	7·80
Suspended solids	—	—	38·7
Soluble solids	—	—	80·4

Number of samples anaylsed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 408,000,000 gallons.
Amount of lime used during the month - 65 tons 14 cwt.
Amount of sludge dealt with during the month - 6,143 tons.
Amount of sludge removed from the works - 247 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·827	1·76	1·04
Albuminoid nitrogen	·123	·370	·172
Oxygen absorbed from $KMnO_4$ in 4 hours	1·75	4·78	3·17
Suspended solids	—	—	11·4
Soluble solids	—	—	82·4

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 66,000000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·914	·914	·914
Albuminoid nitrogen	·265	·291	·278
Oxygen absorbed from $KMnO_4$ in 4 hours	3·87	4·30	4·08
Suspended solids	14·1	14·0	14·0
Soluble solids	83·4	84·2	83·8

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 35
Number of times secondary bed was filled during month - 35
Amount of tank liquor treated per cube yard per 24 hours - 29·0 gallons.
Amount of tank liquor treated during the month - 1,863,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·101	·136	·105
Albuminoid nitrogen	·024	·041	·031
Nitric nitrogen	1·67	2·42	2·10
Oxygen absorbed from $KMnO_4$ in 4 hours	·245	·555	·410
Dissolved oxygen taken up in 24 hours	·7%	·14%	11·4%
Incubator test — Before	·110	·147	·108
Incubator test — After	·070	·200	·134
Suspended solids	—	—	trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - 24 hours' flow
Amount of sludge removed during the month - none.
Amount of sewage treated by the process - 474,200 gallons.

Average analysis of tank liquor—

Ammoniacal nitrogen	1·09
Albuminoid nitrogen	·236
Oxygen absorbed from $KMnO_4$ in 4 hours	4·50
Suspended solids	15·5
Soluble solids	74·1

Number of samples analysed for the average = 1.

Number of times beds were filled during the month - 228
Amount of tank liquor treated per cube yard per 24 hours - 39·5 gallons

Average analysis of final effluent—

Ammoniacal nitrogen	·493
Albuminoid nitrogen	·153
Nitric nitrogen	·860
Oxygen absorbed from $KMnO_4$ in 4 hours	1·20
Dissolved oxygen taken up in 24 hours	·71%
Incubator test — Before	·710
Incubator test — After	·595
Suspended solids	7·4

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

	Leeds filter.	Whittaker filter.	Ducat filter.
Amount treated per cube yard per 24 hours	—	53·3 Unsettled.	—
Ammoniacal nitrogen	—	·110	—
Albuminoid nitrogen	—	·071	
Nitric nitrogen	—	1·18	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	·830	—
Dissolved oxygen taken up in 24 hours	—	30	—
Incubator test — Before	—	·204	—
Incubator test — After	—	·302	—
Suspended solids	—	8·0	—

Number of samples analysed for the average = 2.

LEEDS—*continued.*

March, 1904.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·23	1·78	1·66
Albuminoid nitrogen	·345	·613	·457
Oxygen absorbed from $KMnO_4$ in 4 hours	10·5	10·3	9·11
Suspended solids	—	—	52·4
Soluble solids	—	—	93·4

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 520,500,000 gallons.
Amount of lime used during the month - 82 tons 11 cwts.
Amount of sludge dealt with during the month - 9,774 tons.
Amount of sludge removed from the works - 176 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·69	1·76	1·59
Albuminoid nitrogen	·185	·370	·262
Oxygen absorbed from $KMnO_4$ in 4 hours	1·97	4·78	4·27
Suspended solids	—	—	15·0
Soluble solids	—	—	99·7

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 82,500,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·09	1·05	1·07
Albuminoid nitrogen	·364	·435	·399
Oxygen absorbed from $KMnO_4$ in 4 hours	5·54	5·67	5·60
Suspended solids	19·2	20·1	19·7
Soluble solids	91·4	86·8	89·0

Number of samples analysed for the average = .

Number of times primary bed was filled during month - 46.
Number of times secondary bed was filled during month - 46.
Amount of tank liquor treated per cube yard per 24 hours - 35·3 gallons.
Amount of tank liquor treated during the month - 2,424,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·155	·199	·160
Albuminoid nitrogen	·024	·031	·028
Nitric nitrogen	1·84	2·20	1·97
Oxygen absorbed from $KMnO_4$ in 4 hours	·395	·448	374
Dissolved oxygen taken up in 24 hours	7%	25%	15%
Incubator test — Before	·168	·131	·135
Incubator test — After	·125	·171	·155
Suspended solids	—	—	heavy trace

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of sludge removed during the month - none.
Amount of sewage treated by the process - 663,400 gallons.
Average analysis of tank liquor—
Ammoniacal nitrogen - 1·21
Albuminoid nitrogen - ·262
Oxygen absorbed from $KMnO_4$ in 4 hours - 3·24
Suspended solids - 12·1
Soluble solids - 88·7

Number of samples analysed for the average = 1.

Number of times beds were filled during the month - 285
Amount of tank liquor treated per cube yard per 24 hours - 51·7
Average analysis of final effluent—
Ammoniacal nitrogen - ·602
Albuminoid nitrogen - ·105
Nitric nitrogen - ·380
Oxygen absorbed from $KMnO_4$ in 4 hours - 1·22
Dissolved oxygen taken up in 24 hours - 85%
Incubator test — Before - ·302
Incubator test — After - ·635
Suspended solids - 7·7

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES—

——	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	—	62·3 gallons.		—
	——	Unsettled.	Sand Filtered.	——
Ammoniacal nitrogen	—	·443	·315	—
Albuminoid nitrogen	—	·165	·071	—
Nitric nitrogen	—	·954	·994	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	1·58	·788	—
Dissolved oxygen taken up in 24 hours	—	27%	12%	—
Incubator test — Before	—	·557	·272	—
Incubator test — After	—	·550	·320	—
Suspended solids	—	7·0	4·8	—
Number of samples analysed for the average	—	4	4	—

LEEDS—*continued.*

April, 1904.

SEWAGE—

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·56	2·02	1·68
Albuminoid nitrogen	·605	1·02	·695
Oxygen absorbed from $KMnO_4$ in 4 hours	8·25	12·7	10·6
Suspended solids	—	—	54·7
Soluble solids	—	—	109·0

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 476,500,000 gallons.

Amount of lime used during the month - 75 tons 15 cwts.

Amount of sludge dealt with during the month - 8,780 tons.

Amount of sludge removed from the works - 110 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·64	1·96	1·78
Albuminoid nitrogen	·370	·445	·389
Oxygen absorbed from $KMnO_4$ in 4 hours	3·71	6·70	4·98
Suspended solids	—	—	9·1
Soluble solids	—	—	117·0

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.

Amount of septic sludge removed during the month - none.

Amount of sewage treated by the process - 79,750,000 gallons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·00	1·36	1·18
Albuminoid nitrogen	·316	·385	·350
Oxygen absorbed from $KMnO_4$n 4 hours	5·80	6·32	6·05
Suspended solids	13·1	24·2	18·7
Soluble solids	103·8	92·4	98·1

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 45.

Number of times secondary bed was filled during month - 45.

Amount of tank liquor treated per cube yard per 24 hours - 35 gallons.

Amount of tank liquor treated during the month - 2,329,000 gallons.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·170	·141	·134
Albuminoid nitrogen	·056	.054	·057
Nitric nitrogen	1·82	2·14	2·27
Oxygen absorbed from $KMnO_4$ in 4 hours	·465	.517	·467
Dissolved oxygen taken up in 24 hours	7%	14%	12%
Incubator test — Before	·144	·181	·140
Incubator test — After	.181	·365	·225
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

Exeter Septic Tank Process—

Average daily flow through the tanks	24 hours' flow.
Amount of sludge removed during the month	none.
Amount of sewage treated by the process	629,700 gallons.
Average analysis of tank liquor—	
Ammoniacal nitrogen	1·29
Albuminoid nitrogen	·217
Oxygen absorbed from $KMnO_4$ in 4 hours	3·21
Suspended solids	31·8
Soluble solids	77·5

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	275
Amount of tank liquor treated per cube yard per 24 hours	51·9
Average analysis of final effluent—	
Ammoniacal nitrogen	·465
Albuminoid nitrogen	·081
Nitric nitrogen	1·30
Oxygen absorbed from $KMnO_4$ in 4 hours	1·21
Dissolved oxygen taken up in 24 hours	14%
Incubator test — Before	·495
Incubator test — After	·510
Suspended solids	7·7

Number of samples analysed for the average = 1.

Continuous Processes—

——	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	—	62·3 gallons.		—
——	——	Unsettled.	Sand Filtered.	——
Ammoniacal nitrogen	—	·381	·345	—
Albuminoid nitrogen	—	·169	·104	—
Nitric nitrogen	—	1·12	1·27	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	1·74	1·04	—
Dissolved oxygen taken up in 24 hours	—	41%	28%	—
Incubator test — Before	—	·587	·371	—
Incubator test — After	—	622	·344	—
Suspended solids	—	14·7	6·7	—
Number of samples analysed for the average	—	4	4	—

LEEDS—*continued.*

May, 04.

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst	Average.
Ammoniacal nitrogen	1·41	1·58	1·63
Albuminoid nitrogen	·406	·729	·635
Oxygen absorbed from $KMnO_4$ in 4 hours	8·50	14·0	11·9
Suspended solids	—	—	103·8
Soluble solids	—	—	108·2

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 475,500,000 gallons
Amount of lime used during the month - 75 tons 9 cwts.
Amount of sludge dealt with during the month - 7,546 tons.
Amount of sludge removed from the works - 222 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·23	1·83	1·52
Albuminoid nitrogen	·138	·432	·289
Oxygen absorbed from $KMnO_4$ in 4 hours	3·00	2·52	4·67
Suspended solids	—	—	7·5
Soluble solids	—	—	105·7

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 80,575,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·02	1·23	1·13
Albuminoid nitrogen	·296	·419	·357
Oxygen absorbed from $KMnO_4$ in 4 hours	6·24	6·67	6·45
Suspended solids	22·7	22·5	22·5
Soluble solids	81·0	90·8	85·5

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 45.
Number of times secondary bed was filled during month - 45.
Amount of tank liquor treated per cube yard per 24 hours - 34·5 gallons.
Amount of tank liquor treated during the month - 2,373,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·210	·251	·202
Albuminoid nitrogen	·038	·056	·047
Nitric nitrogen	2·28	2·85	2·25
Oxygen absorbed from $KMnO_4$ in 4 hours	·447	·832	·592
Dissolved oxygen taken up in 24 hours	5%	13%	10%
Incubator test — Before	·131	·228	·172
Incubator test — After	·161	·265	·198
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks	24 hours' flow.
Amount of sludge removed during the month	none.
Amount of sewage treated by the process	647,400 gallons.
Average analysis of tank liquor—	
Ammoniacal nitrogen	·987
Albuminoid nitrogen	·276
Oxygen absorbed from $KMnO_4$ in 4 hours	4·15
Suspended solids	9·0
Soluble solids	85·2

Number of samples analysed for the average = 1.

Number of times beds were filled during the month	278
Amount of tank liquor treated per cube yard per 24 hours	50·5 gallons.
Average analysis of final effluent—	
Ammoniacal nitrogen	·493
Albuminoid nitrogen	·090
Nitric nitrogen	1·32
Oxygen absorbed from $KMnO_4$ in 4 hours	1·22
Dissolved oxygen taken up in 24 hours	40%
Incubator test — Before	·471
Incubator test — After	·440
Suspended solids	4·2

Number of samples analysed for the average = 1.

CONTINUOUS PROCESSES –

	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	—	60·9 gallons.		—
	—	Unsettled.	Sand Filtered.	—
Ammoniacal nitrogen	—	·424	·341	—
Albuminoid nitrogen	—	·135	·079	—
Nitric nitrogen	—	·920	1·05	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	1·61	·928	—
Dissolved oxygen taken up in 24 hours	—	40%	23%	—
Incubator test — Before	—	·618	·314	—
Incubator test — After	—	·628	·320	—
Suspended solids	—	9·4	3·7	—
Number of samples analysed for the average	—	4	4	—

LEEDS—*continued.*

June, 1904.

SEWAGE— *Average Analysis of Sewage.*

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·92	2·37	1·94
Albuminoid nitrogen	·518	·851	·613
Oxygen absorbed from $KMnO_4$ in 4 hours	8·30	15·4	11·3
Suspended solids	—	—	45·0
Soluble solid	—	—	112·5

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 501,250,000 gallons.
Amount of lime used during the month - 80 tons 19 cwts.
Amount of sludge dealt with during the month - 9,173 tons.
Amount of sludge removed from the works - 347 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·90	2·42	2·04
Albuminoid nitrogen	·321	.345	·317
Oxygen absorbed from $KMnO_4$ in 4 hours	3·18	6·40	4·77
Suspended solids	—	—	13·5
Soluble solids	—	—	104·5

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 81,125,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·914	1·02	·971
Albuminoid nitrogen	·305	·311	·308
Oxygen absorbed from $KMnO_4$ in 4 hours	5·84	—	5·84
Suspended solids	33·0	24·4	28·0
Soluble solids	84·4	87·1	78·5

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 44
Number of times secondary bed was filled during month - 44
Amount of tank liquor treated per cube yard per 24 hours - 34·3 gallons.
Amount of tank liquor treated during the month - 2,267,000.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·155	·246	·209
Albuminoid nitrogen	·024	·036	·029
Nitric nitrogen	2·00	1·77	1·88
Oxygen absorbed from $KMnO_4$ in 4 hours	·392	·560	·490
Dissolved oxygen taken up in 24 hours	6%	6%	6%
Incubator test — Before	·127	·168	·144
Incubator test — After	·192	·201	·214
Suspended solids	—	—	heavy trace.

Number of samples analysed for the averge = 3.

Exeter Septic Tank Process—

Average daily flow through the tanks

Amount of sludge removed during the month

Amount of sewage treated by the process

Average analysis of tank liquor—
Ammoniacal nitrogen
Albuminoid nitrogen
Oxygen absorbed from $KMnO_4$ in 4 hours
Suspended solids
Soluble solids
} No further analyses.

Number of samples analysed for the average

Number of times beds were filled during the month

Amount of tank liquor treated per cube yard per 24 hours

Average analysis of final effluent—
Ammoniacal nitrogen
Albuminoid nitrogen
Nitric nitrogen
Oxygen absorbed from $KMnO_4$ in 4 hours
Dissolved oxygen taken up in 24 hours
Incubator test
Suspended solids
} No further analyses.

Number of samples analysed for the average =

Continuous Processes—

——	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	—	63·4 gallons.		—
——	——	Unsettled.	Sand Filtered.	——
Ammoniacal nitrogen	—	·313	·286	—
Albuminoid nitrogen	—	·182	·087	—
Nitric nitrogen	—	1·16	1·24	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	2·17	1·21	—
Dissolved oxygen taken up in 24 hours	—	53%	25%	—
Incubator test — Before	—	·750	·401	—
Incubator test — After	—	·710	·470	—
Suspended solids	—	9·7	3·1	—
Number of samples analysed for the average	—	4	4	—

LEEDS—*continued.*

SEWAGE— July, 1904.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·83	2·15	1·94
Albuminoid nitrogen	·506	·605	·555
Oxygen absorbed from $KMnO_4$ in 4 hours	10·6	13·5	10·9
Suspended solids	—	—	56·5
Soluble solids	—	—	101·5

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 505,750,000 gallons.
Amount of lime used during the month - 80 tons 11 cwts.
Amount of sludge dealt with during the month - 9,558 tons.
Amount of sludge removed from the works - 52 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·91	2·16	1·92
Albuminoid nitrogen	·314	·432	·339
Oxygen absorbed from $KMnO_4$ in 4 hours	3·65	4·88	5·14
Suspended solids	—	—	14·5
Soluble solids	—	—	102·1

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 83,270,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·09	1·07	1·08
Albuminoid nitrogen	·345	·331	·338
Oxygen absorbed from $KMnO_4$ in 4 hours	6·54	7·51	7·08
Suspended solids	21·2	29·0	25·1
Soluble solids	79·0	80·8	87·0

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 45.
Number of times secondary bed was filled during month - 45.
Amount of tank liquor treated per cube yard per 24 hours - 32·3 gallons.
Amount of tank liquor treated during the month - 2,219,000 gallons

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	.141	·195	·186
Albuminoid nitrogen	.024	·041	·030
Nitric nitrogen	1·90	2·00	1·95
Oxygen absorbed from $KMnO_4$ in 4 hours	·510	·478	·454
Dissolved oxygen taken up in 24 hours	0%	7%	4%
Incubator test — Before	·185	·171	·122
Incubator test — After	·200	·177	·162
Suspended solids	—	—	trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks
Amount of sludge removed during the month
Amount of sewage treated by the process
Average analysis of tank liquor—
- Ammoniacal nitrogen
- Albuminoid nitrogen
- Oxygen absorbed from $KMnO_4$ in 4 hours
- Suspended solids
- Soluble solids

Number of samples analysed for the average =

Number of times beds were filled during the month
Amount of tank liquor treated per cube yard per 24 hours
Average analysis of final effluent—
- Ammoniacal nitrogen
- Albuminoid nitrogen
- Nitric nitrogen
- Oxygen absorbed from $KMnO_4$ in 4 hours
- Dissolved oxygen taken up in 24 hours
- Incubator test
- Suspended solids

Number of samples analysed for the average =

CONTINUOUS PROCESSES—

——	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	48·8 gallons.	62·9 gallons.		—
	——	Unsettled.	Sand Filtered.	——
Ammoniacal nitrogen	·494	·251	·175	—
Albuminoid nitrogen	107	·158	·045	—
Nitric nitrogen	·898	1·27	1·30	—
Oxygen absorbed from $KMnO_4$ in 4 hours	1·40	1·98	·847	—
Dissolved oxygen taken up in 24 hours	17%	36%	11%	—
Incubator test — Before	·500	·771	·252	—
Incubator test — After	·542	·828	·277	—
Suspended solids	·85	16·4	9·0	—
Number of samples analysed for the average	4	4	4	—

LEEDS—*continued.*

SEWAGE— August, 1904.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·40	1·58	1·68
Albuminoid nitrogen	·309	·655	·592
Oxygen absorbed from $KMnO_4$ in 4 hours	5·70	14·0	9·52
Suspended solids	—	—	33·5
Soluble solids	—	—	82·7

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 482,250,000 gallons.
Amount of lime used during the month - 78 tons 9 cwt.
Amount of sludge dealt with during the month - 11,414 tons.
Amount of sludge removed from the works - 324 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·74	1·90	1·83
Albuminoid nitrogen	·197	·383	·271
Oxygen absorbed from $KMnO_4$ in 4 hours	1·74	4·00	3·81
Suspended solids	—	—	10·2
Soluble solids	—	—	81·2

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 79,200,000 gallons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·969	1·02	·993
Albuminoid nitrogen	·262	·311	·286
Oxygen absorbed from $KMnO_4$ in 4 hours	5·71	6·62	6·17
Suspended solids	26·5	22·4	24·4
Soluble solids	78·0	78·1	78·0

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 38.
Number of times secondary bed was filled during month - 38.
Amount of tank liquor treated per cube yard per 24 hours - 26·6 gallons.
Amount of tank liquor treated during the month - 1,828,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·161	·202	·181
Albuminoid nitrogen	·034	·036	·035
Nitric nitrogen	2·00	2·47	2·22
Oxygen absorbed from $KMnO_4$ in 4 hours	·371	·548	·460
Dissolved oxygen taken up in 24 hours	0%	7%	4%
Incubator test — Before	·134	·185	·157
Incubator test — After	·044	·400	·214
Suspended solids	—	—	trace.

Number of samples analysed for the average = 2.

Exeter Septic Tank Process—

Average daily flow through the tanks
Amount of sludge removed during the month
Amount of sewage treated by the process
Average analysis of tank liquor—
Ammoniacal nitrogen
Albuminoid nitrogen
Oxygen absorbed from $KMnO_4$ in 4 hours
Suspended solids
Soluble solids

Number of samples analysed for the average =

Number of times beds were filled during the month
Amount of tank liquor treated per cube yard per 24 hours
Average analysis of final effluent—
Ammoniacal nitrogen
Albuminoid nitrogen
Nitric nitrogen
Oxygen absorbed from $KMnO_4$ in 4 hours
Dissolved oxygen taken up in 24 hours
Incubator test
Suspended solids

Number of samples analysed for the average =

Continuous Processes—

	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	46·7 gallons.	59·9 gallons.		—
	—	Unsettled.	Sand Filtered.	—
Ammoniacal nitrogen	·108	·203	·123	—
Albuminoid nitrogen	·038	·110	·041	—
Nitric nitrogen	2·02	1·30	1·40	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·528	1·42	·690	—
Dissolved oxygen taken up in 24 hours	7%	32%	10%	—
Incubator test — Before	·207	·525	·220	—
Incubator test — After	·215	·522	·252	—
Suspended solids	1·2	14·1	6·2	—
Number of samples analysed for the average	4	4	4	—

LEEDS—*continued.*

September, 1904.

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·96	2 32	1·95
Albuminoid nitrogen	·704	·876	·718
Oxygen absorbed from $KMnO_4$ in 4 hours	11·6	13·3	12·5
Suspended solids	—	—	64·2
Soluble solids	—	—	112·4

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 503,756,000 gallons.
Amount of lime used during the month - 76 tons 8 cwt.
Amount of sludge dealt with during the month - 10,469 tons.
Amount of sludge removed from the works - 274 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·66	2·02	1·84
Albuminoid nitrogen	·296	·332	·313
Oxygen absorbed from $KMnO_4$ in 4 hours	5·60	6·28	5·48
Suspended solids	—	—	9·2
Soluble solids	—	—	103·8

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - None.
Amount of sewage treated by the process - 82,500,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·07	1·21	1·14
Albuminoid nitrogen	·423	·350	·316
Oxygen absorbed from $KMnO_4$ in 4 hours	6·52	6·78	6·58
Suspended solids	17·8	20·5	20·2
Soluble solids	95·2	98·5	92·8

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 41.
Number of times secondary bed was filled during month - 41.
Amount of tank liquor treated per cube yard per 24 hours - 29·2 gallons.
Amount of tank liquor treated during the month - 1,942,400 gallons

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·096	·192	·129
Albuminoid nitrogen	·031	·058	·048
Nitric nitrogen	1·75	2·65	2·08
Oxygen absorbed from $KMnO_4$ in 4 hours	·308	·557	·464
Dissolved oxygen taken up in 24 hours	0%	25%	13%
Incubator test — Before	·097	·158	·135
Incubator test — After	·094	·187	·154
Suspended solids	—	—	heavy trace.

Number of samples analysed for the average = 3.

Exeter Septic Tank Process—

Average daily flow through the tanks -
Amount of sludge removed during the month -
Amount of sewage treated by the process -
Average analysis of tank liquor—
- Ammoniacal nitrogen -
- Albuminoid nitrogen -
- Oxygen absorbed from $KMnO_4$ in 4 hours -
- Suspended solids -
- Soluble solids -

Number of samples analysed for the average =

Number of times beds were filled during the month -
Amount of tank liquor treated per cube yard per 24 hours -
Average analysis of final effluent—
- Ammoniacal nitrogen -
- Albuminoid nitrogen -
- Nitric nitrogen -
- Oxygen absorbed from $KMnO_4$ in 4 hours -
- Dissolved oxygen taken up in 24 hours -
- Incubator test — Before -
- Incubator test — After -
- Suspended solids -

Number of samples analysed for the average =

Continuous Processes—

	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	49·9 gallons.	64·4 gallons.		—
	—	Unsettled.	Sand Filtered.	—
Ammoniacal nitrogen	·129	·276	·214	—
Albuminoid nitrogen	·045	·107	·063	-
Nitric nitrogen	1·82	1·25	1·41	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·497	1·48	1·02	—
Dissolved oxygen taken up in 24 hours	7%	33%	21%	—
Incubator test — Before	·167	·505	·317	—
Incubator test — After	·221	·524	·358	—
Suspended solids	1·8	18·4	12·4	—
Number of samples analysed for the average	4	4	4	—

LEEDS—*continued.*

October, 1904.

SEWAGE—

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	2·12	1·96	2·02
Albuminoid nitrogen	·691	1·11	·833
Oxygen absorbed from $KMnO_4$ in 4 hours	9·47	15·4	12.3
Suspended solids	—	—	74·8
Soluble solids	—	—	111·5

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 516,000,000 gallons.
Amount of lime used during the month - 18 tons 1 cwt.
Amount of sludge dealt with during the month - 7,788 tons.
Amount of sludge removed from the works - 288 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·98	2·05	2·08
Albuminoid nitrogen	·370	·568	·418
Oxygen absorbed from $KMnO_4$ in 4 hours	5·54	7·62	6·12
Suspended solids	—	—	12·4
Soluble solids	—	—	102·4

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours' flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 85,250,000 gallons

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·25	1·41	1·32
Albuminoid nitrogen	·483	·493	·489
Oxygen absorbed from $KMnO_4$ in 4 hours	6.87	—	6.87
Suspended solids	28·7	20·5	24·5
Soluble solids	97·0	97·0	94.8

Number of samples analysed for the average = 2.

Number of times primary bed was filled during month - 43.
Number of times secondary bed was filled during month - 43.
Amount of tank liquor treated per cube yard per 24 hours - 29·2 gallons.
Amount of tank liquor treated during the month - 2,009,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·128	·116	·129
Albuminoid nitrogen	·031	·041	·034
Nitric nitrogen	2·45	2·84	2·40
Oxygen absorbed from $KMnO_4$ in 4 hours	·441	·338	·417
Dissolved oxygen taken up in 24 hours	0 %	13 %	6 %
Incubator test — Before	·100	·160	·120
Incubator test — After	·077	·140	·137
Suspended solids	—	—	trace.

Number of samples analysed for the average=3.

Exeter Septic Tank Process—

Average daily flow through the tanks -
Amount of sludge removed during the month -
Amount of sewage treated by the process -
Average analysis of tank liquor—
Ammoniacal nitrogen -
Albuminoid nitrogen -
Oxygen absorbed from $KMnO_4$ in 4 hours -
Suspended solids -
Soluble solids -

Number of samples analysed for the average=

Number of times beds were filled during the month -
Amount of tank liquor treated per cube yard per 24 hours -
Average analysis of final effluent—
Ammoniacal nitrogen -
Albuminoid nitrogen -
Nitric nitrogen -
Oxygen absorbed from $KMnO_4$ in 4 hours -
Dissolved oxygen taken up in 24 hours -
Incubator test — Before -
Incubator test — After -
Suspended solids -

Number of samples analysed for the average= .

Continuous Processes—

	Leeds Filter.	Whittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	49·9 gallons.	64 gallons.		—
	—	Unsettled.	Sand Filtered.	—
Ammoniacal nitrogen	·155	·344	·244	—
Albuminoid nitrogen	·052	·142	·079	—
Nitric nitrogen	2·17	1·32	1·57	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·605	1·65	1·09	—
Dissolved oxygen taken up in 24 hours	10 %	26 %	10 %	—
Incubator test — Before	·220	·660	·420	—
Incubator test — After	·241	·570	·347	—
Suspended solids	3·2	12·1	4·2	—
Number of samples analysed for the average	4	4	4	—

LEEDS—*continued.*

November, 1904.

SEWAGE—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·09	2·28	2·11
Albuminoid nitrogen	·617	·889	·759
Oxygen absorbed from $KMnO_4$ in 4 hours	12.1	8·91	11 5
Suspended solids	—	—	73·0
Soluble solids	—	—	110·8

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 486,250,000 gallons.
Amount of lime used during the month - 78 tons 19 cwt.
Amount of sludge dealt with during the month - 11,105 tons.
Amount of sludge removed from the works - 452 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·16	2·12	2·10
Albuminoid nitrogen	·395	·530	·419
Oxygen absorbed from $KMnO_4$ in 4 hours	3·15	5·90	5·50
Suspended solids	—	—	20·8
Soluble solids	—	—	89·7

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours flow.
Amount of septic sludge removed during the month - none.
Amount of sewage treated by the process - 79,062,000 gallons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·09	1·29	1·18
Albuminoid nitrogen	·364	·493	·429
Oxygen absorbed from $KMnO_4$ in 4 hours	6·64	6·62	6·62
Suspended solids	29·2	18·1	23·7
Soluble solids	79·2	98·8	89·0

Number of samples analysed for the average = 7.

Number of times primary bed was filled during month - 43.
Number of times secondary bed was filled during month - 43.
Amount of tank liquor treated per cube yard per 24 hours - 27·5 gallons.
Amount of tank liquor treated during the month - 1,827,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average
Ammoniacal nitrogen	·168	·125	·141
Albuminoid nitrogen	·038	·038	·038
Nitric nitrogen	2·57	2·20	2·40
Oxygen absorbed from $KMnO_4$ in 4 hours	·095	·345	·267
Dissolved oxygen taken up in 24 hours	10%	24%	17%
Incubator test — Before	·080	·088	·090
Incubator test — After	·020	·044	·051
Suspended solids	—	—	trace.

Number of samples analysed for the average = 3.

EXETER SEPTIC TANK PROCESS—

Average daily flow through the tanks

Amount of sludge removed during the month

Amount of sewage treated by the process

Average analysis of tank liquor—

Ammoniacal nitrogen

Albuminoid nitrogen

Oxygen absorbed from $KMnO_4$ in 4 hours

Suspended solids

Soluble solids

Number of samples analysed for the average=

Number of times beds were filled during the month

Amount of tank liquor treated per cube yard per 24 hours

Average analysis of final effluent—

Ammoniacal nitrogen

Albuminoid nitrogen

Nitric nitrogen

Oxygen absorbed from $KMnO_4$ in 4 hours

Dissolved oxygen taken up in 24 hours

Incubator test { Before / After

Suspended solids

Number of samples analysed for the average=

CONTINUOUS PROCESSES—

	Leeds Filter.	Whitaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours.	48 gallons	62 gallons.		—
	—	Unsettled.	Sand Filtered.	—
Ammoniacal nitrogen	·557	·231	·222	—
Albuminoid nitrogen	·081	·142	·076	—
Nitric nitrogen	1·84	1·62	1·75	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·547	1·55	·800	—
Dissolved oxygen taken up in 24 hours	7%	21%	6%	—
Incubator test — Before	·250	·595	·305	—
Incubator test — After	·131	435	·204	—
Suspended solids	3·0	16·2	8·4	—
Number of samples analysed for the average	4	4	4	—

LEEDS—*continued.*

December, 1904.

SEWAGE— *Average Analysis of Sewage.*

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·98	2·57	2·29
Albuminoid nitrogen	·631	1·21	·929
Oxygen absorbed from $KMnO_4$ in 4 hours	14·7	14·6	14·5
Suspended Solids	—	—	51·7
Soluble solids	—	—	106·0

Number of samples analysed for the average = 4.

PRECIPITATION PROCESS—

Amount of sewage treated during the month - 501,250,000 gallons.
Amount of lime used during the month - 78 tons 18 cwts.
Amount of sludge dealt with during the month - 8,590 tons.
Amount of sludge removed from the works - 575 tons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·56	2·24	1·88
Albuminoid nitrogen	·330	·617	·431
Oxygen absorbed from $KMnO_4$ in 4 hours	5·34	8·95	5·78
Suspended solids	—	—	19·7
Soluble solids	—	—	97·4

Number of samples analysed for the average = 4.

OPEN SEPTIC AND DOUBLE CONTACT PROCESS—

Average daily flow through the tanks - 24 hours flow.
Amount of septic sludge removed during the month - 1,482 tons.
Amount of sewage treated by the process - 82,500 000 gallons.

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	2·05
Albuminoid nitrogen	—	—	·580
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	6·55
Suspended solids	—	—	26·8
Soluble solids	—	—	88·1

Number of samples analysed for the average = 1.

Number of times primary bed was filled during month - 46.
Number of times secondary bed was filled during month - 46.
Amount of tank liquor treated per cube yard per 24 hours - 27·1 gallons.
Amount of tank liquor treated during the month - 1,865,000 gallons.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·184	·224	·175
Albuminoid nitrogen	·022	·043	·034
Nitric nitrogen	2·37	2·61	2·41
Oxygen absorbed from $KMnO_4$ in 4 hours	·245	·481	·331
Dissolved oxygen taken up in 24 hours	4·2%	5·7%	7·1%
Incubator test — Before	·085	·155	·111
Incubator test — After	·000	·200	·095
Suspended solids	—	—	trace.

Number of samples analysed for the average = 3.

Exeter Septic Tank Process—

Average daily flow through the tanks
Amount of sludge removed during the month
Amount of sewage treated by the process
Average analysis of tank liquor—
Ammoniacal nitrogen
Albuminoid nitrogen
Oxygen absorbed from $KMnO_4$ in 4 hours
Suspended solids
Soluble solids

Number of samples analysed for the average =

Number of times beds were filled during the month
Amount of tank liquor treated per cube yard per 24 hours
Average analysis of final effluent—
Ammoniacal nitrogen
Albuminoid nitrogen
Nitric nitrogen
Oxygen absorbed from $KMnO_4$ in 4 hours
Dissolved oxygen taken up in 24 hours
Incubator test
Suspendid solids

Number of samples analysed for the average =

Continuous Processes—

	Leeds Filter.	Wittaker Filter.		Ducat Filter.
Amount treated per cube yard per 24 hours	48·8 gallons.	62·9 gallons.		—
	—	Unsettled.	Sand Filtered.	—
Ammoniacal nitrogen	·419	·275	·272	—
Albuminoid nitrogen	·094	·126	·064	—
Nitric nitrogen	2·14	1·91	2·30	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·611	1·75	1·04	—
Dissolved oxygen taken up in 24 hours	14%	22%	11%	—
Incubator test — Before	·224	·624	·368	
Incubator test — After	·228	·561	·302	—
Suspended solids	2·57	16·8	5·71	—
Number of samples analysed for the average	4	4	4	—

Mr. A. H. Valentine, M.Sc., called in; and Examined.

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22381-2. (*Chairman*) You are Mr. A. H. Valentine, Chemist to the Oldham Corporation, and you have attended here to-day to give evidence with regard to your experience in the treatment of sewage, with particular reference to the Oldham sewage works?—Yes.

22383. What is the general character of the sewage treatment at Oldham?—It is simple sedimentation followed by single contact.

22384. Has the flow of sewage to the Oldham works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather in winter and in summer?—Yes, the flow has been gauged. In the winters of 1903-4 the average flow was 3,352,230 gallons; in the summers 2,265,900 gallons.

22385. What is the maximum dry weather rate of flow, and at what hour does this occur?—The maximum rate is about 6,700,000 gallons per 24 hours, and this occurs between 6 and 7 p.m.

22386. What is the minimum dry weather rate of flow, and at what hour does this occur?—The minimum rate is about 750,000 gallons per 24 hours, which occurs between 4 and 5 am.

22387. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—For about one hour the rate was 36,000,000 gallons per 24 hours. At a slightly lower rate, say about 32,000,000 gallons per 24 hours, the flow has continued for about three hours.

22388. What is the largest number of gallons of sewage which have passed the last storm overflow and come to your works in 24 hours?—Between 24,000,000 and 25,000,000 gallons.

22389. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—Taking the average yearly rainfall as 50 inches, and the drainage area as 4,729 acres, then the volume in gallons would be (assuming $6\frac{1}{4}$ gallons equals 1 cubic foot) about 5,300,000,000 gallons.

22390. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year?—In 1903, when the rainfall was 63·6 inches, the volume of sewage was 2,062,406,000 gallons; in 1904, when the rainfall was 42·45 inches, the volume was 1,682,954,000 gallons.

22391. Is there any infiltration of subsoil water into the sewers, and, if so, does it occur regularly, or does it vary with the seasons or with the state of the weather?—Yes, the amount varying with the character of the weather. After continued wet weather there is, roughly speaking, an infiltration of more than two million gallons per diem. After a lapse of two to three weeks, with dry weather intervening, the infiltration is practically nothing.

22392. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of these effluents? Do you find that they interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise?—Only a small volume of trade effluent enters the sewers. There is, on rare occasions, a small volume of dye waste to be observed, likewise dirty lubricating oil sent down by large ironworks in the town. The most objectionable trade waste, if it be correct to term it trade waste, is the black matter—partly liquid, partly solid—which is received from mill lodges or reservoirs. This waste is simply an oversepticised, stagnant, and extremely concentrated sewage, containing an abnormal amount of black foully smelling sludge. As a rule, this matter is sent down the sewers during the week end, more particularly in summer time, and previous to and during holidays. It exercises an adverse effect upon the filters, an influence which is exercised for several days with detriment to subsequent efficient action. It would be impossible, I think, to give the volume thus sent down. However, it is relatively small, compared with the general flow. I have made no special analyses of the sewage at the particular time at which this waste arrives, but I have found that the oxygen absorption for the day's sewage has very considerably increased on such a day. The wastes from slaughter-houses and tripe-dressing establishments are only noticeable for the amount of small particles of coagulated fat. This is arrested, either in the detritus pits or in the fore parts of the settlement tanks. This waste, otherwise, has no objectionable feature.

22393. In dry weather what is the average amount of suspended matter in the Oldham sewage, and what are the highest and lowest figures, in parts per 100,000?—Taking dry weather to mean days without rainfall, the whole of 1903 and 1904 included, the average amount of suspended matter in parts per 100,000 in Oldham sewage was 47·9. The minimum was 10; the maximum 188·6. The former was obtained on the first fine day after continuous rain late in 1903, and the latter was due to the before-mentioned cause—the emptying of mill lodges.

22394. What is the physical character of these solids?—The solids generally are in a fine but flocculent condition. They are for the most part, I should say, of the nature of disintegrated cellulose (paper and waste cotton), and also of dissociated fats and soaps.

22395. Can you give us average analyses of the Oldham sewage for the years 1903 and 1904 in summer and in winter?—These analyses, in grains per gallon, are to be found in the monthly returns which I have handed in. The figures, in parts per 100,000, are:—

——	Amm. N.	Alb. N.	Cl.	Oxygen from $KMnO_4$.	Dissolved Oxygen.	Oxygen from $KMnO_4$ corresponding to preceding.	Suspended Solids.
Summer	3·48	·847	10·39	6·40	10·51	7·10	58·0
Winter	2·86	·691	8·46	4·80	6·77	5·44	44·5

22396. Is it a strong sewage, and, if so, what characterises its strength, and does its strength vary very much from hour to hour or on different days of the week?—Apart from Monday and Tuesday, and occasionally Wednesday, I am inclined to say that Oldham sewage might be classed as "weak." On the first three working days of the week there is a very great amount of soapy and fatty matter—the suspended solids in the sewage are generally high on these days. These days, especially Tuesday, seem to be utilised as domestic "washing" days. In dry weather, the afternoon sewage on these days is quite white when looked at in bulk. This liquid, when settled, is difficult to purify, and only a few of the oldest and most efficient filters are able to cope with it. I have also noticed on Tuesdays that a fair amount of coagulated fat comes down the main sewer. The greater part of this is probably sent down by tripe dressers.

22397. How do you think "strength" of sewage as affecting purification is best expressed or measured?—By the chlorine content, and the amount of oxygen absorbed in four hours from acid $KMnO_4$.

22398. Have you any information as to the bacteriological condition of the sewage?—No.

22399. Are there any chemical poisons in the sewage?—I think not. Very rarely I have noticed an odour of carbolic acid and tarry substances in the sewage.

22400. Is the sewage always alkaline?—I test our liquors occasionally. Litmus is not affected. The sewage and tank effluent are both alkaline to Methyl Orange, and slightly acid to Phenol Phthalein. This is probably due to the presence of Ammonium Carbonate and an excess of CO_2 in solution.

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22401. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—It almost invariably happens that, for some hours, the length of time depending upon the intensity of the rainfall, the amounts of suspended solids in a sewage are greatly increased. As time goes on the amounts decrease, until they are at length appreciably less than in normal flows. I may possibly have some figures to hand in later on.

22402. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—Everything points to the fact that the sewers have sunk in places, thereby allowing solids to accumulate. The reasons in support of such a statement are (1) the comparatively large amount of sub-soil water obtaining access to the sewers; (2) the great amount of suspended solids brought down during the earlier periods in times of small rainfall; (3) the suspended solids in the first part of a storm sewage are not of a ferruginous nature. The detritus of Oldham streets is of this character.

22403. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate your answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—I have made a few special analyses of the liquid part of the sewage in storm times. Judging by the smell, the appearance, the difficulty evinced by the filters in dealing with the first portion of settled storm sewage after a period of dry weather, and the results of certain analyses, I have come to the conclusion that this portion of a storm flow, apart from its suspended matter, is a very polluting liquid, and that in spite of dilution of the sewage during the earlier portion of a storm under the above-mentioned conditions, this dilution is more then neutralised by the impurity brought into solution by the storm water. As regards the succeeding portions there is no doubt that the suspended solids account for by far the greater part of impurity.

In a few cases the experiments were done both with settled and filtered sewage.

The following figures give the results of half-hourly analyses of raw storm sewage, and the corresponding filtered (through filter paper) samples for a slight storm of about 3½ hours' duration, after a week's dry weather. The sample taken at 9.30 p.m. on Saturday is one taken some few minutes before any storm water had apparently put in an appearance at the Outfall works. Under ordinary circumstances the sewage taken late on Saturday evening is a weak, purely domestic sewage.

PARTS PER 100,000.

	Raw Sewage.	Filtered Sewage.	Rate of flow per 24 hours.
	4 hours O. absorption from $KMnO_4$.	4 hours O. absorption from $KMnO_4$.	
9.30 p.m. (first sample of storm water)	2·97	1·74	about 2,800,000
10.0 p.m.	8·51	2·03	,, 14,000,000
10.30 p.m.	8·64	2·20	, 16,000,000
11.0 p.m.	5·94	1·77	,, 12,000,000
11.30 p.m.	8·67	1·89	,, 12,000 000
12.0 midnight	8·29	1·60	,, 9,000,000
12.30 a.m.	5·76	1·46	,, 6,000,000
1.0 a.m.	5·60	1·46	,, 5,000,000
1.30 a.m.	4·77	1·51	,, 3,500,000

The following are typical analyses of samples of sewage and tank effluents during fairly wet weather :—

OXYGEN ABSORPTION TEST.—Parts per 100,000.

	Raw.	Settled.	Filtered.
Sewage	3·16	2·27	1·63
Morning's tank effluent	1·70	1·13	0·97
Evening's tank effluent	3·09	2·60	1·97
Sewage	3·50	—	1·04
Morning's tank effluent	3·00	—	0·97
Evening's tank effluent	3·07	—	1·19
Sewage	3·37	—	1·73
Morning's tank effluent	2·00	—	0·87
Evening's tank effluent	2·83	—	1·60

The following are typical analyses of samples of sewage and tank effluents after a few days' fine weather :—

THIRD DAY AFTER RAIN.

	Raw.	Settled.	Filtered.	
Sewage	11·47	—	3·29	Monday's "washing-day" sewage.
Morning's tank effluent	3·81	—	2·33	
Evening's tank effluent	6·50	—	3·86	

FIFTH DAY AFTER RAIN.

	Raw.	Settled.	Filtered.
Sewage	5·46	3·74	2·46
Morning's tank effluent	3·86	3·50	2·27
Evening's tank effluent	4·89	4·46	2·64

The following are analyses of samples of storm water taken during storm on April 4th, 1905 :—

RESULTS IN PARTS PER 100,000.

O. absorption 4 hours from $KMnO_4$ Raw Sewage.	O. absorption 4 hours from $KMnO_4$. Filtered Sewage.	Rate of flow in gallons per 24 hours.	Time.
4·60	1·99	6,480,000	10.20 a.m. (immediately previous to first flush of storm water)
6·83	2·54	8,880,000	10.50
7·77	4·25	14,160,000	11.20
10·31	2·77	15,360,000	12.20 p.m.
7·14	2 86	21,120,000	1.20
7·14	2·30	19,680,000	2.20
10·31	1·56	22,080,000	3.20
10·74	1·67	21,120,000	4.20
6·97	1 99	9,600,000	5.20
5·87	2·61	8,160,000	6.20
6·97	3 41	6,000,000	7.20
13·91	2 70	5,280,000	8.20
4·71	2 27	4,340,000	9.20

22404. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm? I should be glad if you would state your views fully on this question, and if you would also tell the Commission what number of dilutions you think it practicable to treat in one or another way?—I am not favourably inclined towards the arbitrary rules affecting the treatment of storm water laid down by the Local Government Board, although I fully appreciate the difficulty that would probably arise were such rules not to obtain, in respect of cases in which sewage works are controlled or managed by unintelligent working foremen. This condition of things is more often than not in the case of the smaller sewage works. As the detailed question suggests, the first portion of storm sewage, especially after a period of dry weather, is of a very polluting nature. I would send all such sewage, even though it were in volume above six times the normal flow, partly through the

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ordinary settling tanks, and partly—the greater portion—through special storm tanks of considerable capacity, with or without chemical treatment as one thought fit. This first portion I would treat by the ordinary method—if the contact system were in use—adopted in dry weather—that is, by contact in filter beds for a certain number of hours. Should the storm continue it would be quite sufficient to run the subsequent highly diluted and settled sewage continuously through certain filters—such filters need not of necessity be used solely for such a purpose. They could be treated occasionally with weak settled (or precipitated) sewage during dry weather in order to keep them "in condition." I think it would be advisable to have such storm filters in reserve so that in cases of emergency the majority of such filters would be at one's instantaneous service. There are times, in the early morning especially, after a previous heavy rainfall, when I have found that the raw sewage, even though it be flowing at only about three times the normal rate, is a non-putrescent liquid. Such a liquid probably deteriorates in character by sending it through settling tanks already containing a fair amount of sludge, and it would be preferable if it were possible to turn this liquid directly into the ordinary watercourse. There can be no doubt that the greater portion of such a sewage is subsoil water. It would then be unnecessary labour, etc., to run such sewage through settling tanks and subsequently upon filters. As regards the question of choking, there seems to me little risk of that. I have noticed no falling off in capacity when the ordinary filters have been requisitioned as storm filters. Of course, the sewage has had a preliminary settlement, which, at any rate, has removed the coarser suspended solids. It is from these that the danger of choking might arise. The addition of chemicals, such as copperas or one of the proprietary precipitants, might cause or facilitate the settlement of the very finely-divided suspended matter, but I cannot speak with certainty on this point. In Oldham sewage the greater portion of this finely-divided matter still remains in suspension, even after 12 hours' standing in a bottle; and as this matter is entirely mineral-ferruginous—as it arises from the finer particles of mill ashes used for various purposes in the construction and maintenance of Oldham streets, I see no reason why one should remove or even attempt to remove such. Hence I should not advocate the use of chemical precipitants during the later portion of a storm flow.

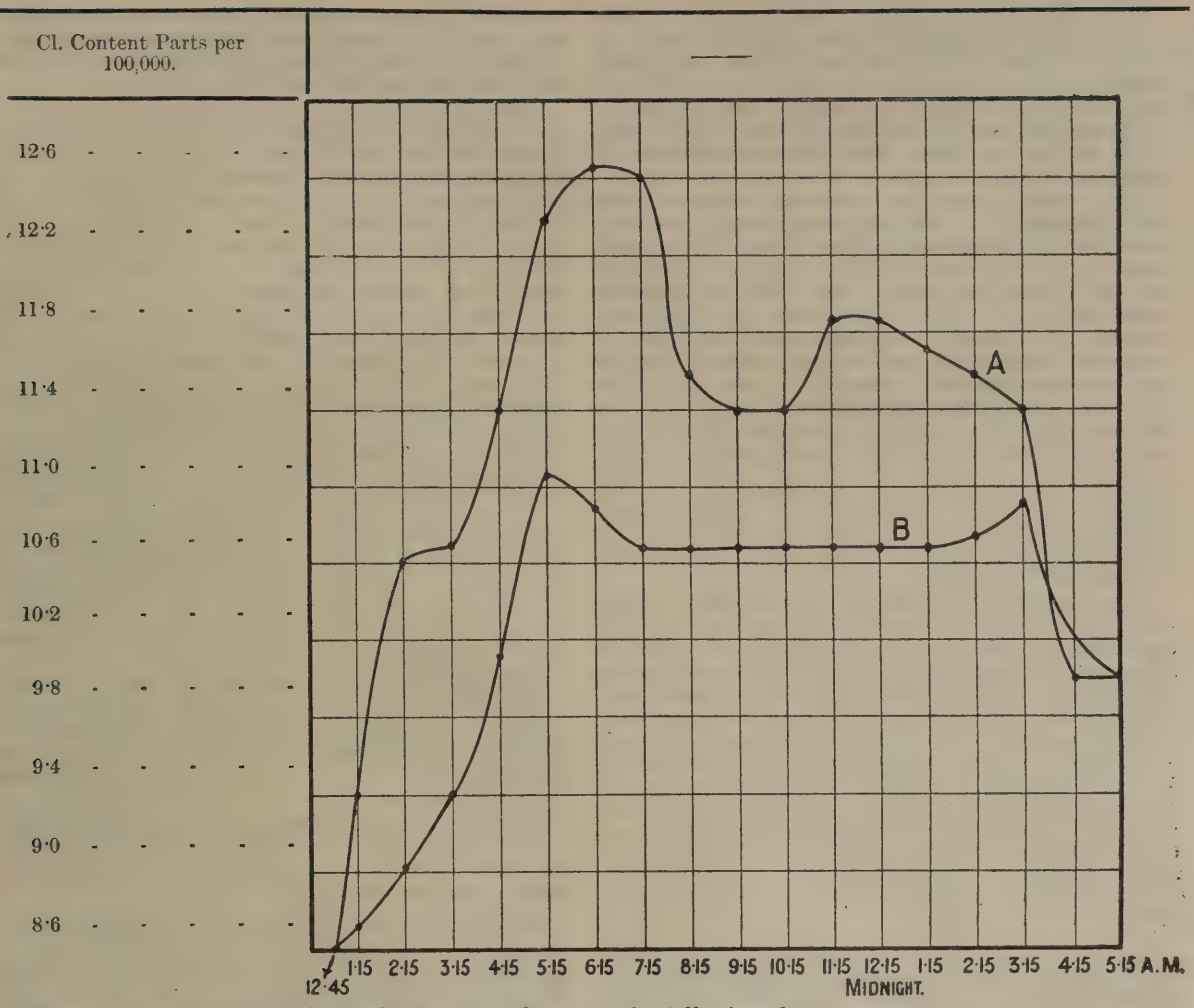
22405. What are your views with regard to storm overflows?—It would be best, in my opinion, which is based mainly on theoretical knowledge, if there were only one overflow on any system of sewers. This overflow I should prefer to be of a movable pattern, situated at the end of the main sewer adjacent to the sewage disposal works. It might be advisable, and even necessary in the case of a scattered or hilly district, especially in a district with a high rainfall, to have additional overflows along the sewage system, otherwise the drains must be, of necessity, of an inordinately large size. In this particular case overflows might best be placed at or near the end of the branch main sewers serving the several and separate colonies of streets. It would apparently be impossible to utilise movable overflows in such positions. Where a relatively large volume of subsoil water finds entrance to the sewers in a short space of time owing to the peculiar geological formation and nature of the strata underlying the surface, perhaps additional overflows in connection with the branch sewers might be necessary. This necessity might be overcome by placing small drains below the sewers to draw off water of this nature. As regards the form of overflow serving the sewers before the outfall works are reached, I know of none which is relatively superior to others, and I see no end to be served in adopting a standard form of overflow. At the outfall works I prefer a movable sluice, so fixed that the overflow invariably finds its way over the top.

22406. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight while in others this would not be the case?—I assume that streams other than those utilised for drinking purposes are in question. I think that whatever the condition or size of stream the nature of the storm sewage, whether treated or not, should be of a good nature—that is, it should have no odour reminiscent of sewage; it should pass the incubator test, and it should have practically no coarse suspended matter. The greater portion of the suspended matter should be of an inorganic nature, otherwise it is probable that the second condition will not be fulfilled. As regards the condition of the stream higher up, if bad, that would be a matter requiring consideration from above-stream authorities. It is quite possible, as the question suggests, that in some circumstances—and here one's thoughts naturally alight on the case of non-manufacturing districts—no injury would be caused to the stream were the overflow or overflows to come into operation when the number of dilutions was smaller than the number laid down by the Local Government Board. This seems to me a case requiring settlement or adjustment by a kind of local Rivers Conservancy Board.

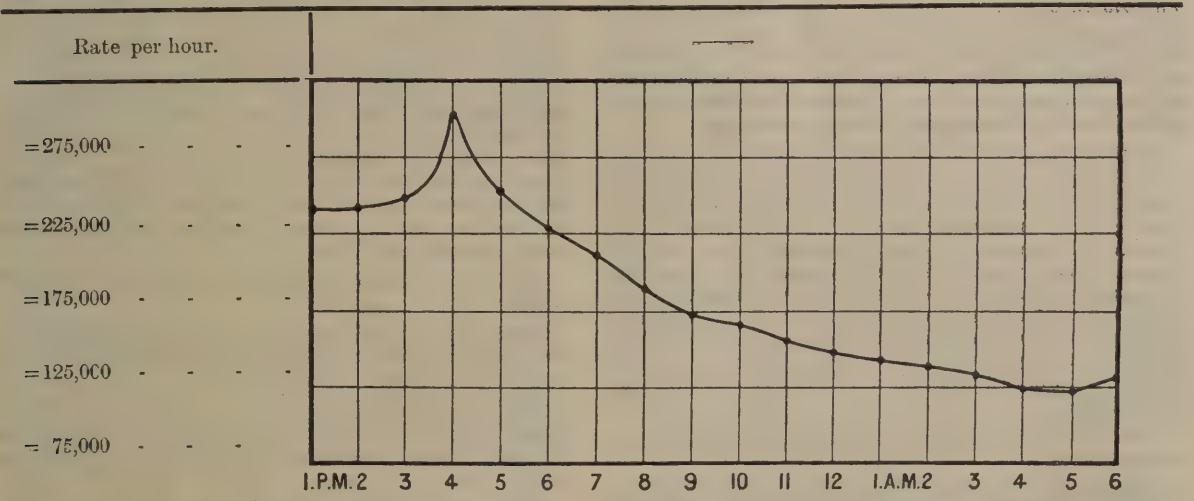
22407. Do you consider that in certain circumstances road water should be purified?—Yes, decidedly so; the first portion washed down by a storm.

22408. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers? Initial outlay as well as annual cost should be borne in mind?—I am disposed, from knowledge and not from practical experience, to prefor the combined system of sewerage. Naturally the great objection, an objection which, however, has not found much weight with large local authorities, is the increased capital outlay caused by the construction of sewers of much greater capacity than those that would be necessary to deal with a theoretical dry weather flow, in addition to the outlay requisite to deal with storm water by means of tanks and filters. I have mentioned theoretical because, unless due and expensive precautions were made, the foul water sewers on the separate system would take their share of subsoil water. On the other hand, to be set against this is the capital outlay incurred in the construction of two drainage systems in a town adopting the separate system. Although I can speak with no practical authority on this point, I should think that the latter capital outlay, if the scheme were carried out in a proper and effective manner, would exceed the former. Whilst "combined" sewers are flushed and cleaned at times by storm water, mechanical arrangements for flushing would have to be adopted on "separate" sewers in order to keep them clean. In conformity with the opinion expressed in my preceding answer, a certain purification area should be set aside to deal with the first portion of road, etc., storm water, unless there were some device by means of which such water could be turned into the foul water sewers. This would obviously entail capital outlay. There is also the question of upkeep of a double set of drains and sewers to be taken into account should the use of a separate system be invoked. In conclusion, I may state the opinion that filters work better if occasionally filled with settled or precipitated dilute sewage, as will happen if a combined system of sewerage is used.

22409. Is your sewage settled, and if so how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—Our sewage is settled. It is allowed to flow through a certain number of tanks, each with a capacity of 175,000 gallons We have twelve such tanks at Oldham, and, generally speaking, there are nine or ten in use at once; less in summer. I have made experiments as to the rate of flow through a tank. In order to do this, slightly over 1 cwt. of common salt was dissolved in a small wooden tank of water, and the solution was emptied into the entrance end of a tank at 12.45 p.m. Immediately preceding this, however, two samples of tank liquor in this tank were taken, one at the entrance end, the other at the exit end. The chlorine figures were respectively 9·4 and 8·6. Subsequently samples were taken every half-hour at the exit end of this tank until 5.15 a.m. the following morning. In order to ascertain how the salt worked its way through the tank samples were taken every two hours from the exit end of the *adjacent* tank. When, finally, the two chlorine contents coincided, I concluded that for all practical purposes the entire salt solution had worked its way through the tanks. The following diagram illustrates the course of the experiment:—A represents the variations as to time and chlorine content in the tank receiving the salt; B represents the variations as to time and chlorine content in the adjoining tank.



The rate of flow through the main sewer is shown in the following chart:—



Although the greatest rate of flow is generally between 6 and 7 p.m., here it occurs between 4 and 5 p.m. In this instance I calculate that the Cl. content reaches its highest limit (6.15 p.m.) after a total flow through all the tanks of about 1,200,000 gallons, which is equal to nearly $\frac{3}{7}$ this day's flow. There were seven tanks in use, not including the septic tank, through which the rate of flow is exceedingly small. The tank operated upon had been in use about six days, and as there were probably between 5 in. or 6 in. of sludge in the tank I calculate that the available tank space was reduced from 175,000 to 162,000 gallons. According to the above diagram, it will be seen that even with a normal dry weather flow it is impossible to say how long a certain portion of sewage remains in the tanks. Given, however, a uniform rate of flow throughout the day, and an even flow through the tanks, containing theoretically no sludge, the salt solution in this experiment should have taken about 12 hours to flow through. In times of storm the length of time is rendered still more variable, inasmuch as the additional flow occasionally reaches the volume of 22,000,000 gallons per diem. The following numbers in parts per 100,000 represent the average analysis of the tank liquor for the years 1903–04, in parts per 100,000:—

Ammoniacal N	Albuminoid N.	Chlorine.	Oxygen absorbed from $KMnO_4$ in 4 hours.	Suspended Solids.	Dissolved Oxygen absorbed from Aërated Water.	Oxygen absorbed from $KMnO_4$ in 4 hours, the samples corresponding with the sample used for Dissolved Oxygen Test.
3·22	0·537	7·39	3·06	15·8	5·39	3·40

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22410. What time would be necessary for you to gain a good tank liquor containing, say, no more than 6 or 8 parts of suspended solids per 100,000 from your sewage (without the addition of chemicals)?—About 15 hours by continuous flow settlement. This, of course, holds good only when the tank effluent is not septic, which condition of things often obtains at Oldham in warm weather.

22411. Do you prefer to use settlement tanks in series or in parallel?—I would prefer a combination of both, though I have had no personal experience of tanks used in series. I have often thought it might be possible to use all the tanks in parallel, and finally to send the combined liquors from these tanks into one large tank, where it is probable that the lighter form of suspended matter, or the black suspended matter from tanks which have become septic (even though the "septic" system is not used), will settle, and where further septic action may continue. There are, of course, other forms of the combined system which it might be advantageous to use.

22412. In the case of continuous flow tanks, do you think there is any advantage in the employment of baffling boards or walls?—If I understand the question in the right way, I don't see much advantage in using baffling boards and walls.

22413. How is the sludging of tanks done at your works, and what is the character of the sludge?—The character of the sludge varies with the season. In the summer and autumn it is more difficult to press, using the same proportion of lime, than in the winter and early spring. This is due probably to two causes:—(1) Less road and mineral matter is brought down in the summer, as the rainfall is less, thereby increasing the percentage of fat in the sludge; (2) the sludge is more acid in character. Hot weather and a slower flow through the tanks induces septic action in a very short time, and I take it that one molecule of a higher fatty acid or compound is decomposed into several molecules of less complex and simpler fatty acids. Hence more lime is needed for neutralisation.

22414. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—I am in favour of the first-mentioned operation as a preliminary to settlement. I should think, contrary to what the question would suggest, that this is more economical than the alternative mentioned later. I think it would be a very difficult matter to effectively screen our sludge.

22415. What is the manurial value of your sludge, and will farmers take it?—The farmers in the neighbourhood, up to a radius of 4 or 5 miles, are willing and glad to take our sludge. It is, however, first pressed with lime. The cost of removal devolves upon them. It is very probable that its manurial value would be greatly enhanced were the fatty bodies and the greater part of the moisture removed. I had some analytical figures referring to the composition of the sludge, but they are mislaid or lost. I shall attempt to gather fresh data to place before the Commission in the early future.

22416. Are there any chemical poisons in it?—I do not think so.

22417. Do you find any nuisance from the treatment of sewage in settlement tanks. Have any complaints been made?—No.

22418. Have you had any experience of the chemical precipitation of sewage?—Yes, a little.

22419. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—No. I think that a sewage, especially a strong one—that is, treated reasonably with precipitants, taking special care not to add any excess of lime—is more easily purified by subsequent filtration than the same sewage subjected to settlement only. The sewage at Oldham is not chemically treated as a general rule, though for the past two years, during warm, dry summer weather, I have added thin milk of lime and a solution of copperas to it with beneficial results. The precipitants render aid in throwing down the very finely divided suspended solids which are so difficult to remove by settlement alone. I think that the addition of chemicals in the usually small proportions in which they are added to the sewage, has little effect on impurities in solution. Of the two systems just mentioned and of the septic system I am inclined to prefer the last.

22420. Have you tried various chemicals?—Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—Yes, in the shape of aluminoferric, and a combination of lime and copperas. I could not distinguish any difference between the two with regard to the subsequent filtration. I am inclined to believe, however, that if the lime and copperas are added judiciously, such a combination will prove more efficient and cheaper than the proprietary precipitants. Of course, I am thinking more particularly of Oldham sewage, which contains a relatively large amount of soapy and fatty matter. The great advantage—if advantage it really be—of proprietary precipitants is that they are dissolved by the washing action of the sewage itself, and thus no apparatus or plant for preparation and distribution is required. Such an advantage will be more apparent in a small sewage works. Another disadvantage attaching to the use of proprietary precipitants consists in the fact that approximately the amount dissolved is proportionate to the rate of flow. This is fairly satisfactory in dry weather, but there is no doubt a great waste of material when diluted sewages are treated.

22421. What is the most effective way of adding chemicals?—Apart from proprietary precipitants, by previously dissolving (or diluting in case of lime) the chemicals. In this way the addition of the chemicals is easily controlled, according to the varying strength and volume of the sewage.

22422. What is the character of the suspended matter in the liquor from your precipitation tanks?—Partly flocculent, possibly from sludge already settled in the tanks, and partly soapy.

22423. Do you find it necessary to add further chemicals to the sludge before it can be dealt with? If so, for what reasons, and what chemicals do you use, and how are they added?—Yes, in the form of lime. The soapy and fatty matters will not press, but when fully combined with lime as calcium stearate, etc., no difficulty presents itself. The following is the method of mixing, though personally I am in favour of some modification. The lime is first slaked to the consistency of a more or less fine powder. It is then added from canvas bags to a fixed quantity of sludge in the sludge channel, which receives directly the sludge through valves from the settling tanks. Mixing by manual labour follows, after which the sludge is allowed to flow by gravitation into an ejector and thence by air pressure to the presses, seven in number, viâ three large rams, acting as reservoirs.

22424. Does the sludge contain any chemical poisons?—No.

22425. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—No.

22426. As regards septic tanks, how should they be shaped?—I am in favour of rectangular tanks, with sloping bottoms, the deeper end being at the entrance wall.

22427. Should they be divided into sections?—I have no decided opinion on the matter, as my experience of others than the plain rectangular tanks has been but small. However, I have a preference for tanks divided into two sections. The first section might be of sufficient length to retain the heavier particles, say, one-fifth or one-sixth the total length of tank. By some mechanical arrangement this heavier matter could be removed as it accumulated without interfering for any serious length of time with the working of the tank.

22428. Should they be used in series or in parallel?—On this question I would refer you to my answer to Question 22411 in reference to the use of ordinary sedimentation tanks.

22429. Is a scum necessary or desirable?—I do not think so. As a rule, a scum shows that the sludge already in the tank is in more or less active decomposition. I think that this decomposition of the sludge aids in a way, the nature of which I do not know, the decomposition of the liquid flowing through the tank; but when once septic action is started it is unnecessary to have

any great accumulation of sludge in the tank. By working under these conditions the probability is that if there be any scum it will be of a very ephemeral nature, its existence depending a great deal upon the atmospheric conditions above.

22430. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—I do not think so. I see no advantage in having a closed septic tank except that, with such a modification, the scum is undisturbed by atmospheric disturbances. This, however, as I have said, is a matter of no consequence. As regards the utilisation of the gas evolved from the septic tank, I strongly doubt whether it be worth while to lay down a plant efficient enough to collect and distribute it to the various quarters of a sewage works.

22431. What do you consider the best arrangement for the "feed" and "draw-off"?—I see no reason why the ordinary surface methods of "feed" and "draw-off" should not be used. If, however, the practice is to allow the sludge to accumulate to a considerable depth, I think it would be advisable to "draw-off" about 18in. below the surface, in order to prevent large pieces of scum issuing from the tank, and so going upon the filters.

22432. At what rate is sewage, as a matter of custom, passed through your septic tanks?—At Oldham we have a closed septic tank, with an under "feed" and an under "draw off." It is very difficult to gauge the rate at which the sewage is sent through this particular tank. It would not be far wrong to say that the volume of sewage sent through the tank was about one-third or one-quarter the volume sent through one of the ordinary settling tanks if not less. As to the rate of flow, that is an entirely different matter, because this tank is not far from being full of sludge at the present time.

22433. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous?—Between 20 and 24 hours I think, inclining to the latter mentioned number, but I have not sufficient data to state a confident opinion as to the disadvantage accruing from a quicker passage through the tanks. On the other hand, it is quite possible that a slower rate might act to advantage. But from observation I should say that with a strong sewage, if the rate be such as to enable the sewage to flow through in two-thirds the time stated, the tanks are working under disadvantageous conditions. The slower rate is preferable, as partial hydrolytic decomposition of complex organic bodies is then well developed, and the filters, so I take it, are more capable of dealing with the simpler products of such decomposition than with the more highly organised bodies originally present.

22434. Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with?—I consider that weak sewage—dealing, of course, with the same particular sewage works—may well take a shorter time to pass through the tanks. So that dealing with one particular sewage, I think that the tank capacity need not be increased should the volume of sewage increase up to two or three times the normal dry weather flow.

22435. Is it possible to "oversepticise" a sewage, and, if so, for what reasons, and how is the "oversepticising" brought about?—Yes. Under such a condition of things there is probably an excess of the ultimate products of decomposition, such as sulphuretted hydrogen, carbonic acid, and the simpler organic bodies, such as the lower mercaptans, amines, and acids. The filter beds have great difficulty in dealing with such a liquid. These conditions are, as a rule, brought about by having too slow a rate of flow through the tanks, and by allowing the contents of the tank to lie stagnant.

22436. What is the amount of digestion in your septic tanks, and how do you calculate this?—How far do you find that the digestion is affected by the atmospheric temperature?—I have insufficient data to go upon, though I think that the amount of digestion or solution is much smaller than was originally supposed to be the case. I find that the character of the effluent is affected to a small extent by changes in atmospheric temperature. During very warm and dry weather "oversepticising" is prone to occur. At any rate, septic action is promoted, so that in dry cold weather it might be of advantage to have a smaller rate of flow than with the same volume of sewage per diem in hot weather.

22437. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning, and then remove all the sludge?—Of the alternatives presented I prefer the former. When once septic action has set in, the periodical removal of a quantity of the sludge has the effect of decreasing the amount of suspended matter in the tank effluent, and by having recourse to such a procedure I have observed no retardation of septic action. On the contrary, such a removal of sludge possibly encourages septic action, as by such means a greater tank capacity is obtained.

22438. How do you think the sludge should be taken out of the tank, and how should it be disposed? Does any nuisance attend the operation?—For a short time during the latter end of 1902, a somewhat dry period, I made an attempt to use our settlement tanks as septic tanks. I succeeded to some extent. At any rate the effluent was what I may perhaps term "semi-septic." During this period as soon as sludge gathered to an appreciable extent in any tank, I caused the sludge outlet valve in the exit wall of the tank to be slightly opened. The tank was meanwhile working. By this means sludge was forced slowly into the adjacent sludge channel at a lower level by the mere pressure of the water above in the tank. As soon as the sludge appeared too thin I had the valve closed. I found it was unwise to continue this at any one time for a considerable length of time; and it was best to let a day intervene before this process was again put into operation. In this way the sludge had time to level itself up in the tank. One great disadvantage with which we had to contend lay in the fact that our sludge valves were (and are) actuated by loose chains pulled by hand, thereby rendering a nice adjustment of the valve a matter of some difficulty and great patience. There are other methods, of course, of partially removing the sludge, but they could not be used at Oldham without structural alterations requiring the expenditure of much time and money. The sludge thus obtained was disposed of in the same way as sludge from settled sewage—that is, by mixing with lime and pressing. This is further treated of in a previous answer, No. 22413. No nuisance attended the operation of removing the sludge.

22439. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tanks?—Yes. This is only natural.

22440. Should any portion or the whole of the sewage which arrives at the outfall works in times of storm be passed through the septic tanks?—I am in favour of sending the first portion of storm sewage, especially after dry, hot weather, through the septic tanks, should they be in such a condition as suggested in my answer to No. 22438, and subsequently limiting the flow through them to not more than twice or thrice the normal rate of flow. I find that the filters are improved by an occasional dosing with weak sewage.

22441. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank, and, if so, can you give us figures (in parts per 100,000) showing what the increase is?—Very little difference in the amount of suspended matter is caused by increasing the rate of flow up to twice or thrice the normal rate when only a small amount of sludge is in the tank. This condition is necessary. By sending the whole storm flow through, the increase in suspended solids depends greatly upon the amount of suspended matter in the sewage, and the amount of sludge already in the tanks. I have made determinations of the suspended matters issuing from our septic tank in dry weather and during rainfall, and the figures I have obtained at various times have led me to the above conclusions. But they are so variable, owing to the gradual accumulation of sludge in the tank, that I think no useful purpose can be served by my giving random figures.

22442. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank

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liquor? Kindly state what observations you have made on this point along with what you consider the reasons for advantage or disadvantage of the one or other process?—Yes. Both my predecessor and myself have tried and compared the three methods, and independently we have come to the conclusion that a septic-treated sewage is the one that can be most efficiently dealt with on filters. There are these advantages attending the use of a septic system: (a) A more equable tank effluent is obtained; (b) the tank effluent is in a better condition for subsequent treatment—that is, the organic impurities are in a simpler condition than when they are passed through settling tanks, and, therefore, fewer difficulties lie in the way of purification by contact or continuous treatment; (c) a certain amount of digestion of solids is induced; (d) no expense is incurred by the addition of chemicals. On the other hand, there is, no doubt, a decided tendency to an increase in suspended matter in the tank effluent, though I find that this is to a great extent overcome by occasionally and partially removing the sludge from the tanks whilst they are still in operation, and by using an under "draw-off." This disadvantage could be sensibly reduced, or, perhaps, entirely overcome, by using tanks in series, or, better, by a combination of tanks in parallel and in series, as suggested in a previous answer.

22443. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—I have made no estimations or experiments beyond my ordinary routine work on this point, but observation tends to confirm the general opinion that there is a very material difference between the respective impurities in solution—I have found that a septic tank effluent contains 3 to 4 parts in 100,000 excess in solution over a settled sewage effluent.

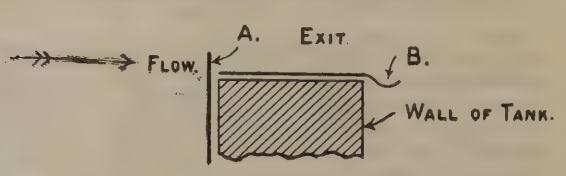
22444. Have you any data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints?—No.

22445. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—No.

22446. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—Yes—about 10 or 11 parts per 100,000.

22447. How do you consider that this can best be done?—By adopting the system of septic tanks in series. As I have stated before, I have had no practical experience of this method. For a large sewage works I have not much faith in roughing filters.

22448. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?—I have seen for a fairly long period the septic modification of three-chambered septic tanks used in Manchester. They were fairly successful, I believe, but not to the extent that was hoped for. It might be advisable to have the last compartment of greater capacity. At Oldham one of our tanks used some years ago as an open septic tank was fitted with an arrangement in sheet zinc, diagrammatically shown in section.



The strip A of sheet zinc is placed about 1 in. from the tank wall, and it dips 18 in. under the surface. B is also of sheet zinc. It serves its purpose fairly well, preventing large lumps of floating scum from working their way over the tank wall, but the volume of settled sewage in the tank must be kept within reasonable limits.

22449. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—Where adjacent beds are on or about the same level, one may well dispense with the use of building material. At Oldham, the sides of the filters are, where necessary, puddled, and invariably boarded up by 3-inch planking. I think it necessary, where two adjacent filters are far from being on the same level, to puddle or concrete that portion of the bottom or sides where leakage is likely to take place.

22450. Do you find within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—Yes. At Oldham we work between limits of 1½ ft. and 3 ft. I have had no experience with contact beds with a greater depth than 3¼ ft., and hence have no means of judging as to the efficiency of deeper beds. Probably the main point to be considered is that of aeration. It is possible that there is a depth beyond which, in order to work the bed a reasonable number of times per week, efficient aeration cannot be attained.

22451. What do you consider is the most convenient size for a contact bed?—That, I think, should depend upon the rate of flow of the tank effluent supplying the bed. The smaller the bed is, the quicker may it be filled and emptied, and this will enable it to be filled more frequently. At present, and until some structural alteration can be made, we have two beds which take between three and four hours to fill. So long as the bed is well-drained, so long as sufficient means are taken to aerate the bed when empty, and so long as the bed can be filled within a reasonable time without disturbing the surface of the bed, the fact suggests itself that there is no limit to the size of the filter. On the other hand, a large bed, measured superficially, would require a corresponding number of surface distributors, and, more important still, of drains which, towards their upper ends, would require to be more or less branched. This angular branching would probably be a deterrent to the efficient aeration, as possibly would be a multiplicity of primary drains. Taking all these factors into consideration, and judging from what I have seen, I think no bed should measure superficially much beyond one-third of an acre, and the bed should be as near as possible in the form of a square.

22452. What do you find to be the best filtering materials?—I have had experience of two materials—mill ashes and vitrified clinker burnt at a high temperature in refuse destructors. Of the two, the clinker is to be preferred. It disintegrates much less readily than the more friable ashes.

22453. What size should the filtering material be, and should it be graded in the beds?—Our beds are filled with clinker passing ½-inch mesh. Otherwise it is not graded in the beds. Small material in the bed is apt to promote clogging and choking. However, we place very coarse lumps of clinker immediately over and around the drains. This was done merely to prevent small particles of clinker obtaining access to the drains, and so partially choking them. I have heard it stated that the large clinker help more completely to empty the bed when it is being run off. This is very probable.

22454. How should the bottom of the bed be constructed?—I have no particular preference so long as the beds and the drains can naturally empty themselves when the valves are open. For this reason, the bottom should in all ways slope towards the end containing the outlet valves. At Oldham the bottom of any bed is ridged out, the drains occupying the valleys formed by adjacent ridges. With these two provisions it is not possible for water to lodge anywhere in the bed on its being emptied. Perhaps I may express the opinion that the construction of channels covered by perforated slabs leads to a great deal of quite unnecessary outlay. Our drains are put together in two-foot lengths. Each length is separated about one inch from the neighbouring length. In our latest beds each length is well perforated throughout, and here we have recourse to a loose spigot and socket arrangement, though, of course, we find no necessity for using cementing material.

22455. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—Yes, decidedly so.

22456. What periods of filling, standing full, emptying, and standing empty, do you consider best in practical working (a) for primary beds, and (b) for secondary beds?—The period of filling should obviously be as short as possible, so long as the surface of the bed be not disturbed. But this will depend upon various factors—the size of the bed, the method of distribution, and the flow of sewage at the time. I think that 75 or 90 minutes should not be exceeded in the process of filling. I adhere to no hard and fast rule as to the time

allotted to a bed standing full. The time depends upon (1) the age of the bed; (2) the time of the year; (3) the time of the day; (4) the day of the week; (5) the strength of the sewage and tank effluent. At Oldham we vary from one hour to five or six hours, and occasionally even more. In emptying, the valves are about quarter opened until the beds are half empty. The samples are then taken, after which the valves are opened as widely as possible. The emptying, not including the draining, should not take more than 1½ hours. In general practice I give 2 to 6 hours standing empty and draining, the time depending very much upon the same factors as are considered in the time allowed for contact. As regards secondary beds, the time of standing full would doubtless depend upon the character of the liquid from the primary bed. It may be quite sufficient to fill the bed, and then immediately proceed to stream it through at the same rate as it leaves through the valves. If a contact is desired it is probable that one of an hour's duration would be quite sufficient.

22457. If you have had experience of automatic gear for filling and emptying contact beds, would you kindly give your views?—I am not favourably impressed with any automatic gear I have seen for filling and emptying contact beds. They are apt to get out of order for some reason or other; and as they are invariably adjusted to rigid times of contact, etc., I am, if only for this reason, strongly against their use. Manual labour I consider is, in the long run, much cheaper, safer, and more reliable.

22458. What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed in 24 hours?—Assuming a tank liquor which absorbs 3½ parts in 100,000 of oxygen in four hours from $KMnO_4$, and also assuming a bed two or three years old, I think that, working the bed to the uttermost within the limits of efficiency, the filter could well take between 120 and 140 gallons per cube yard per diem. During very dry weather in Oldham, and especially during the earlier portion of the week, when the sewage is at its strongest, the tank effluent may absorb 8 to 10 parts of oxygen, and in that case 80 to 95 gallons could be treated per cube yard.

22459. What amount of liquid from a primary bed can in practice be properly treated on each cubic yard of filtering material of a secondary bed in 24 hours?—I have had very little experience with secondary beds, but drawing a conclusion from general knowledge and slight practice, I think a secondary bed ought to take nearly three times the quantity passed through a primary bed.

22460. Can these quantities be increased by more frequent filling and emptying in times of storm without impairing the efficiency of the beds or the quality of the effluents?—I should say that just as one could fill a primary bed more often during times of storm, so secondary beds could well bear the same treatment. In fact, I see no reason why a well-settled storm tank effluent should not be streamed directly through secondary beds for hours at a stretch.

22461. Is one contact sufficient for the conversion of some tank liquors into a satisfactory effluent?—Assuming a tank liquor which absorbs 3½ parts in 100,000 of oxygen in four hours from $KMnO_4$, and also assuming a bed two or three years old, I think one contact would be sufficient to ensure a satisfactory effluent, or effluent that would remain non-putrescent on incubating, and one, according to my experience at Oldham, that would very rarely absorb as much as 1·25 parts of oxygen per 100,000 in four hours from $KMnO_4$. Almost without exception, such effluents, if they have an odour at all, possess a pleasant earthy smell, and are clear except for a slight opalescence, which, as a general rule, may be put down to the presence of unchanged soapy matter.

22462. At what rate or rates do primary contact beds and secondary contact beds lose their water-holding capacity? It would be convenient to regard the capacity of the empty contact bed, *i.e.*, the tank before the filtering material is added, as 100, and to express the capacity from time to time in parts of this figure?—I cannot give the data in detail asked for in this question. At the same time I may state that we have no very accurate means of registering the capacity of any bed. However, measurements have been made from time to time, and they are, I fancy, pretty approximate. They are stated below, and these measurements may be taken as applying to the general run of filters at Oldham.

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Time in use.	Capacity of bed.
7 years	19 per cent.
5½ ,,	19 ,,
5 ,,	20 ,,
4½ ,,	22½ ,,
3 ,,	28 ,,
2¼ ,,	30 ,,
1½ ,,	35 ,,
1¼ ,,	36 ,,
¾ year	41 ,,

The capacity of a bed when first filled is about 56 per cent. Of course, the material, in the course of its being placed in the bed, has been subject to this usual atmospheric conditions of snow, rain, etc.

22463. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed or to the fineness or coarseness of the material of the bed, or on what does it depend?—What the exact influence the two factors mentioned exercise upon the capacity of a bed it is difficult, I think, for any one to say. On considering the volume treated, one must also take into account the strength of the liquid treated, apart from any consideration of suspended matter, at any rate of the coarser suspended matter. Up to a certain limit it is quite possible that small quantities of suspended matter in a tank effluent exercise very little influence in affecting the capacity of a bed. The gelatinous matter that one usually finds in a filter bed is, I believe, an aggregated deposition from solution. This condition of things is more likely to arise when a tank effluent contains a fair amount of very finely divided matter in solution, a liquid which one might term opalescent. A fine bed will lose its capacity at a greater rate than will a coarse bed, because this matter is more readily deposited on the more closely associated fine material. Another factor playing an important part in the matter is the disintegration and settlement of the material itself. Judging from observation, the surface of the bed made of mill ashes sinks between 1½ and 2 inches per year, at any rate during the first year or so of its existence. This entails a double loss of capacity if it be the rule to fill the bed to the surface of the material.

22464. Can the material of a clogged bed be washed?—I have had no experience in the matter. Considering, however, the experience of others, I think it would pay to wash the material of a clogged bed if the process of disintegration has not already been carried too far.

22465. How can the capacity of contact beds be best maintained?—The use of a hard vitrified material would doubtless obviate to some extent the loss due to disintegration. However, the loss due to deposition of the before-mentioned gelatinous material would still go on, and I see no means of keeping the rate of loss of capacity as low as possible, except by using them on fewer occasions. That would then entail the construction of additional beds. I find that resting for periods has practically no effect upon the ultimate capacity of a bed. I find that an occasional use as continuous storm filters raises the capacity slightly. If there is any reasonable means of maintaining the capacity of a bed up to a fair degree I shall be very glad to know of it.

22466. What is the average analysis of your single contact effluent?—Average for the years 1903, 1904, single contact, in parts per 100,000, ammonia, nitrates in terms of N:—

Amm. N.	Alb. N.	Nitric N.	Chlorine.	O. from $KMnO_4$.	Dissolved O. from Aerated Water.	O. from $KMnO_4$ corresponding to preceding.	Suspended Solids.
1·51	0·235	0·317	8·32	0·99	1·43	1·13	5·1

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22467. What number of gallons of liquid are treated daily per cubic yard of filter material in your beds?—This is a very variable quantity. My views as to the amount which can be treated have already been given in Answer 22458.

22468. Do you find any chemical poisons in your final effluent?—I should think there are no chemical poisons.

22469. What is the average amount of suspended matter in the primary bed effluent? Does most of this matter come out with the first flush or not?—Average amount of suspended matter in primary effluent equals 5·1. The very finely divided suspended matter is pretty well distributed, though most of the coarser material comes out with the first flush. The drainings are, as a rule, pretty free from any form of suspended matter.

22470. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed is different from the organic matter of the suspended solids going on to that bed?—I have made no analyses bearing on the chemical differences between the organic matter of the suspended solids going upon and the organic matter of the suspended solids issuing from a filter bed. There is a distinct difference in physical characteristics. The suspended matter from the tank is flocculent and coarse, and generally black, and invariably of a putrescent nature. That from a filter bed is of a very fine description, rarely visible as individual particles, and in the great majority of cases seems to bear no adverse influence in the incubator test. It is either probably unchanged soapy matter or growths of an elementary vegetable nature. Its volume, as a rule, increases greatly under the influence of the incubator.

22471. Is the first flush of effluent from either set of beds ever putrescible?—Yes ; this is generally the case, especially where strong tank effluents are treated.

22472. Do you find that by increasing the number of fillings in storm times or other times the amount of suspended solids is increased?—In storm times, when I have filled the filters continuously there is generally more than the average amount of suspended solids, but it is nearly all of a mineral nature. If a bed be overworked in dry weather the effluent has a tendency to contain more suspended matter.

22473. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency ; and, if so, do you think there are advantages in so working them?—This method has been practised at Oldham, and I have found no unfavourable results accrue. As a matter of fact, the system works extremely well. This is seen when there is a gradual gradation from stormy to fine weather. In the case of a summer storm, however, succeeded at once by fine hot weather, two or three fillings subsequent to the storm-water dosing give an effluent of an unsatisfactory nature. Under ordinary circumstances, however, the filters seem to be "freshened up," if I may use the expression. I have also noticed that after the filters have been used as storm filters there seems to be an appreciable increase in capacity in the beds.

22474. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per 24 hours in ordinary times and in storm times?—We have single contact only. The depth of all beds constructed since 1899 is uniformly 3 ft. Those built prior to 1899 vary from 1 ft. 6 in. to 2 ft. 9 in. Assuming all the beds to be one uniform depth of 3 ft., they have been filled by contact at the rate of about 350,000 gallons per acre per 24 hours during the years 1903 and 1904. This does not include the amount treated on the filters when they have been used continuously for storm water. The actual volume treated by contact is really less than the above-mentioned number, when one takes into account the filters which are less than 3 ft. in depth. The filters have rarely been filled more than twice per day, apart from their use as continuous storm filters, because with the labour at command and the work to be performed a double filling per day is about the utmost that can be done. Otherwise it would be possible to fill them four or even five times per day in fairly wet weather.

22475. Have you made any experiments which throw light upon the action of contact beds when full and when resting?—Yes. At Manchester I carried out a few analyses of the gases found at different depths in contact beds. During the same period an experiment was carried out showing the great absorptive power for oxygen of the gelatinous material found within the body of a filter and its emission of CO_2. From comparative analyses I have concluded that oxidation and nitrification more readily take place near the top than near the bottom. By varying the depth of liquid in the bed I have found that the best condition for working the bed, having regard to purification, is to have the liquid fairly well showing through the uppermost layer of filtering material. Probably by this intimate association of liquid, clinker, and the atmosphere the liquid more readily takes up oxygen from the atmosphere, and transmits it to liquid at a lower level.

ANALYSIS OF GASES FROM BACTERIA BEDS.

Experiments performed at the Manchester Sewage Works, 1901.

Length of rest.	Depth at which sample was drawn.	Percentages.		
		CO_2.	Parts per 10,000.	O.
2 hours' rest -	6 ins.	Nil.	—	—
" " " - -	1 ft. 6 ins.	0·8	80	15·2
" " " - -	2 ft.	2·0	200	12·0
4 hours' rest - -	6 ins.	Nil.	—	18·0
" " " - -	1 ft. 6 ins.	Nil.	—	17·4
" " " - -	2 ft.	2·8	280	4·8
7 days' rest - -	1 ft. 6 ins.	2·6	260	9·6
" " " - -	2 ft.	Nil.	—	18·0
6 hours' rest - -	1 ft. 6 ins.	0·2	20	18·2
7 days' rest - -	1 ft. 6 ins.	3·2	320	12·8
The above bed washed the previous day with Town's water.	1 ft. 6 ins.	4·6	460	10·0

These results are approximate, as the experiments were performed with an Orsat apparatus.

22476. Have you made a study of the conditions of aeration of contact beds ; and, if so, with what results?—The best results are obtained by affording all possible means of access of air to the filters. It is my impression, which has been strengthened by several observations, that the introduction of vertical vent pipes at the upper ends of the drains at the bottom of the beds serves a good purpose in aiding aeration. On placing two stoppers moistened with strong hydrochloric acid and strong ammonia respectively about a foot down one of the above-mentioned vents, the white cloudy ammonium chloride formed, though specifically heavier than air, mounted readily to the top of the vent into the air. The valves commanding the drain should also be fully opened during the period of rest.

22477. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—No ; no complaints have been made.

22478. Have you had any experience of percolating filters?—I have but a passing acquaintance with the system of filtration by percolation. It is possible that at Oldham we may have constructed in the near future a filter or filters constructed on the continuous system. My knowledge of these filters has been obtained by visits to works employing the system. I have opinions on the merits of the system, but naturally, as they are not based on practical experience, I doubt whether it be worth while to state them. On the whole, I may say that, as far as I have seen, my mind is favourably impressed with the system, if carried out in an intelligent way.

22479. Would you kindly compare the cost (initial expenditure and annual cost of upkeep and working) and relative advantages of percolating filters and contact beds? Do you consider that one form is best for some kinds of sewage, and the other form for other kinds of sewage?—As regards initial expenditure, and speaking in general terms, I think that, taking both systems under the most favourable conditions, it is likely that a greater initial outlay is required in the construction of percolating filters. I consider that a great deal of money has been thrown away, up and down the country, in the elaborate construction, in some cases somewhat on the type of Roman tesselated baths, of contact beds. As has been mentioned previously, it matters little, having regard merely to the efficient filtration of tank effluent, whether the sides and bottoms of filters should be constructed with such expensive material as concrete, blue brick, etc., or in the natural ground. With percolating filters, on the other hand, as far as I know, it seems to be necessary to have recourse to the use of a fair amount of brick or concrete work, in addition to the use of mechanical means of distribution, either of the revolving or of the stationary type. On account of the great depth of beds in the percolating system, the question of levels often proves a matter of great difficulty, and in the event of such a difficulty arising one would be compelled to consider the cost of pumping the tank effluent to a sufficient height in order not only to allow it to fall upon the filter, but also to actuate the revolving machinery, etc., usually used in this system. Where land is difficult to obtain, the exigencies of the case all point to the adoption of the percolating system. When one comes to consider the cost of upkeep, the balance would seem to incline towards the percolating system. Where the levels are favourable enough to obviate the necessity of pumping, the cost of upkeep naturally would be very slight. The great disadvantage attaching itself to the contact system seems to be practically absent with the percolating system if only a large and hard enough material be used as a filtering medium. I refer to the settlement, the disintegration, the choking which are so distressingly prevalent in beds of the contact type, and which, directly and indirectly, add so much to the proper maintenance of the system. With land easily available, labour and good filtering material cheap, it may be more economical to employ the contact system. The experience of others seems to bear out that one system will more readily deal with some kinds of sewage or treated sewage, and the other system with other kinds. How to classify these kinds is difficult, but I fancy that the percolating system will more readily adapt itself to the treatment of septic tank liquids in which the tank effluent is of a less complex nature than the effluent obtained from a settled or precipitated sewage.

22480. Do you find that the chance of nuisance is any greater with one form of filter than with another? Does the risk of nuisance depend on the kind of sewage which is being treated, or on the nature of the preliminary treatment to which the sewage has been subjected? The question of nuisance is important and I should be glad if you would state your views fully on these points?—From my experience in sewage works, the question of nuisance is one that has been and is greatly exaggerated. For example, at the Manchester Sewage Works I have heard occasionally of complaints as to smells. These, I am confident, have generally emanated from neighbouring farms—not always the most salubrious of spots—and sometimes, in hot weather, from the adjoining Ship Canal. However, it is probable that, on works where the sludge and the screenings are placed upon or ploughed into the soil, a nuisance might arise. Again, it is not unusual to notice a disagreeable odour on sewage farms employing the land filtration system. The spraying of liquors upon percolating filters generally gives rise to a sour, disagreeable odour, due probably to the cooling of the liquid sprays as they fall through the air.

22481. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor or tank liquors could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds?—I have made no definite comparative observations on the issue raised except those already stated. Assuming a tank liquor which absorbs 3½ parts in 100,000 of oxygen in 4 hours from $KMnO_4$, and also assuming a bed 2 to 3 years old, I believe there is little difference between the two systems. As time goes on, however, the advantage probably lies with the percolating system, as that system seems capable of treating a constant volume of tank effluent per day. Under the contact system, this volume grows less in time, owing to the continued loss of capacity, which, as far as my experience shows, is not counterbalanced by a corresponding increase in efficiency, beyond a certain limit. Again, with a strong tank liquor, the advantage would possibly lie with the percolating filter, whilst in dealing with a more or less diluted tank liquor the contact bed would work more satisfactorily, inasmuch as the times of filling, of contact, of resting, may be lengthened or shortened at will. With a percolating filter there seems to be a limit, very soon reached, beyond which it is impossible to put any more liquid upon it in a given time.

22482. Have you had any experience of storm water filters? If so, would you kindly give us the results of it?—The storm filters at Manchester were first put into use during my assistantship there. If it be not presumptuous to say so, I think that the storm filters there were (and I suppose are) utilised in a very judicious fashion. At Oldham I have had occasion to use the ordinary filters as streaming storm filters during periods of very heavy flow, with very satisfactory results, judging from the percentage of purification reached, and with no detriment, but rather otherwise, to the beds.

22483. Do you consider storm water filters lose any of their efficiency by being used intermittently at long intervals?—I have not worked under these conditions, but I should think that storm filters would work more efficiently if they were worked intermittently at short intervals. Not only so, but I think that all available filters should be used as opportunity offers. If at present I had storm filters at my disposal, I should use them in their turn three or four times a week, and use them as a whole, for the filtration of the Sunday flow, which contains appreciably less suspended solids than on other days, is more purely domestic, and is at the same time much less in volume than weekday sewage.

22484. Have you any practical suggestions to make for disposing of sludges?—In consequence of the general adoption of waste water closets in Oldham, the sewage of this borough contains a large amount of soapy matter either in solution (colloidal) or in fine suspension, probably in a partially dissociated condition. I have made analyses of the sludge deposited in the tanks, and have found, after acidifying the sludge with sulphuric acid, an amount of matter extractable by benzene equal to 24 per cent. of the dried sludge. This extract, though of a dark appearance, has all the physical and chemical properties of stearic acid. It is very probable that, by acidifying the sewage before it entered the tanks, a greater amount of stearic acid could be obtained. On certain days of the week, the tank effluent, and, to a less extent the resulting filtered effluent, contain a great amount of opalescent soapy matters, which probably might be removed by the previous addition of sulphuric acid or other chemicals. A more economical method of obtaining the grease has been tried in the laboratory at Oldham. Using a very simple apparatus, an apparatus that it would be an easy task to improve, a portion of the fairly dried acidified sludge was distilled under reduced pressure, at a pressure of about 50 c.m. of mercury. Notwithstanding the fact that, in bulk, this dried sludge is a very bad conductor of heat, a good quantity of fatty acid distilled over and was collected in warm water. It was of a lightish brown colour, and much better in appearance than the sample extracted by benzene. It was evident that, with an improved apparatus, one more amenable to the required changes in temperature and pressure and more under controllable conditions, practically the whole amount of fatty acid could be obtained. This method in principle is now being worked on the large scale at Bradford, Yorkshire, and I understand that the plant laid down there has been devised by the joint labours of Dr. Grossmann, of Manchester, and Mr. Garfield, the Sewage Works Engineer of Bradford. Mr. Garfield has informed me that, judging by some rough experiments of his own, practically the whole of the nitrogen still remains in the sludge after the fat is distilled off. If this be the case—and I have not yet verified the statement—the fat-freed and water-free sludge would be of invaluable use as a manure. Its value would doubtless be enhanced by judicious mixing with small quantities of lime (to counteract acidity), and probably of basic slag, to ensure a greater percentage of phosphates. To work under the most favourable conditions it would be advisable to prevent, as far

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as possible, the entrance of storm water, with its abundance of suspended mineral and waste organic matter, into the tanks, except those set apart for storm-water treatment. When one considers the market price of stearic acid, even in the crude state, and the probable cost of laying down and maintaining a plant large enough for dealing with the sludge deposited in normal weather, it seems within reason to venture the opinion that, looked upon from the commercial standpoint alone, the process would exceedingly well pay its own way, in addition to the part or even whole maintenance of the other branches of the sewage works. And one must not lose sight of the fact that, under present conditions, the entire cost of sludge disposal in most towns, including Oldham, is a dead loss. In this town the cost may be put down as £1,400 per annum at least.

ESTIMATION OF EXTRACT (BY BENZENE) OF DRIED ACIDIFIED SETTLING TANK SLUDGE.

The time the tank was in use.	General character of the weather.	Percentage of fatty extract from the dried sludge.	Mineral matter in the sludge.
9 weeks	Very rainy	11·0	59
9 „	„ „	12·2	55
9[1] „	„ „	10·2	55
12 „	Earlier portion—very wet ; Later portion—fairly wet	12·3	54
10 „	Fairly wet	19·7	47·3
9 „	Normal weather	23·6	49
14 „	Fairly wet	17·8	
14 „	Wet, but storm water excluded as far as possible from the tank	21·9	

TYPICAL ANALYSIS OF BENZENE EXTRACTED. ACIDIFIED SLUDGE, DRIED AT 105°C.

Volatile matter of which
N = 2·1 per cent. } = 45 per cent
C = 28·0 per cent. }
Soluble Silica = 10 per cent. }
Clay = 6 „ „ } = 40 „ „
Sand = 24 „ „ }
Fe_2O_3 (apart from clay) - - - = 4·3 „ „
Al_2O_3 („ „) - - - = 0·5 „ „
Ca O („ „) - - = 4·2 „ „
Mg O („ „) - - - = 1·1 „ „
So_3 and alkalies - - - - - not estimated.
P O - - - - - - = 1·4 per cent.

The fat extracted from the dried acidified sludge (an average sample) by commercial benzene amounted to 21·5 per cent.

Melting point of this fat* = 41°C.
Saponification equivalent (milligrammes of K O H required to neutralise 1 gramme of the fat) = 175
Saponification equivalent of pure Stearic Acid - - - - = 197

22484*. What, in your opinion, constitutes a good effluent?—It is impossible, I think, to define in set terms what constitutes a good effluent. In the following opinions I am influenced by what I observe at Oldham. A good effluent will, in general, possess several characteristics all more or less prominent according to the degree of efficiency. Taking first the physical characteristics, an effluent, if possessing any smell, should have a pleasant earthy odour. In appearance it should be fairly bright and clear, and not more than reminiscently opalescent. I find that, taking these superficial tests alone as a criterion, my judgment is very seldom at fault on subsequently subjecting the effluents to the more exacting test of the incubator, which I regard as the ultimate test. With respect to the four hours' oxygen absorption from $KMnO_4$, it is very unwise and wrong, in my opinion, to adjudge this or that effluent good or bad according as it is on this or that side of a fixed arbitrary line defined by a particular test. I have had effluents which absorbed less than one part of oxygen in 100,000, which, at sight, I would class as bad, and which, speaking for the greater number of these samples, became putrescent in the incubator. On the other hand, there have been effluents which have absorbed nearly three times this amount of oxygen, of a good appearance, and which have remained "sweet" after six days' sojourn in the incubator. From consideration of my own figures, I feel more than favourably disposed to Professor Dunbar's (of Hamburg) opinion, that in this particular test the predisposition or otherwise to become putrescent is determined in the very great majority of cases by the percentage purification undergone by the tank effluent in the filter. If I remember rightly, Professor Dunbar fixes the maximum at 60–65 per cent., and this, according to my experience at Oldham with a strong domestic sewage, is a sufficiently high percentage of purification. Thus a filtered effluent absorbing one part of oxygen in 100,000 obtained from a tank effluent absorbing two, or slightly more, parts of oxygen in 100,000 is much more likely to be unsatisfactory than an effluent absorbing 2·00 parts of oxygen obtained from a tank effluent absorbing 6·00 parts, or more, of oxygen in four hours. In conclusion, I cannot dogmatise so far as to say that I would like to see this test applied to all sewages. It is possible that with a sewage containing a large volume of trade effluent, especially of waste chemicals, such a test would bear too hardly.

22485. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—My experience with percolating filters is too slight to enable me to form any decided opinion on the matter. So far as my little experience goes, it is possible that, with the abnormal amount of suspended matter removed from a percolating filter effluent, this effluent may be more satisfactory than an effluent from a contact bed. As this suspended matter is generally of a somewhat large and flocculent nature, there should be no great difficulty, allowing, of course, a reasonable time for settlement, in removing the greater portion by far of this matter.

22486. Have you tried the "aeration" test—*i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—Yes.

22487. Is one standard for all effluents passing into non-potable streams possible and desirable?—I think not.

22488. Should there, then, be more than one standard, and, if so, how should a plurality or series of standards be formulated? What amount of suspended matter would you allow in an effluent?—Standing by the previously-expressed opinions, it seems just as impossible to formulate a plurality of standards as to set up one rigid standard. Efficient and frequent inspection, with advisory and plenary powers pertaining to such inspection, will probably be the best means of ensuring the efficient working of the various sewage works throughout the country. The idiosyncrasies of every sewage disposal works in every district should be pretty well known to the official or officials in charge of any centre of inspection. As the second part of the question suggests, the amount of suspended matter, especially organic, in an effluent, plays a great part in the character of that effluent. Speaking in general terms, the more suspended matter there is in an effluent—not considering a storm water effluent—the greater is the tendency for that liquid to become putrescent, the more so as the proportion of organic matter increases. From observation at Oldham, I should say that effluents containing under five parts of suspended matter per 100,000 are generally satisfactory. On filtering an opalescent effluent through filter paper, between 100 and 150 c.c. must be rejected before the filtrate becomes really clear. If this be not done, the amount of suspended matter in a liquid possessing, say, five parts of such matter may read as low as 2·5 or 3 parts per 100,000, which, of course, is a wrong reading. An excess of suspended matter seems to act as foci around which growths of a bacterial or vegetable mould charac-

* This sample of fat probably contains a small amount of benzene homologues from the extracting liquid, hence the comparatively low melting point.

ter may foster and develop. This condition of things, specially where the other tests are unsatisfactory, almost invariably leads up to putrescence when the liquids are subjected to incubation.

22489. How far do you consider it advisable for a sewage installation to be worked automatically?—I am adverse to the use of any automatic installation with respect to the filling, emptying, etc., of contact filters. If I am not wrong, all such installations are worked to a rigid time cycle, and no—or, at least, only inadequate—allowances can be made for variations in flow, strength of liquor treated, etc. Furthermore, these automatic systems are all liable to become deranged. Their repair, coupled with their initial cost, will be found to exceed the cost of the equivalent manual labour, which it need hardly be said is of a safer and more reliable nature.

22490. Have you made any systematic observations as to the effects of discharging effluents of known volume and known composition into watercourses of approximately known volume?—No.

22491. Could you say briefly the values you attach to the different chemical tests in use for determining the qualities or conditions of sewage and effluents?—This has been treated to some extent in answer to previous questions. I have expressed opinions as to the oxygen absorption and incubator tests. It is likely that the albuminoid nitrogen test may be amenable to treatment somewhat on the same lines as the O. absorption test. It is probable that with a percentage purification of 55 or above, comparing the filtered effluent with the parent tank effluent, a filtrate is likely to keep non-putrescent in the incubator. As regards the test for nitrates, I am afraid, contrary to the general opinion, that I find in the Oldham effluents that the amount of nitrate present has very little relation to the other tests, and it has but little influence on the incubator test. With reference to the "dissolved oxygen" test, my analyses have been usually done with the *average* filtered effluent for any day, and not with individual filter effluents. With the data at command I think that a higher percentage purification is desirable with this test than is requisite with the O. absorption from $KMnO_4$ test. Perhaps 70 per cent. purification would not be too high.

22492. What are your views with regard to the quantitative determinations of the "strength" of a sewage, tank liquor, etc.?—With regard to the usual tests applied in the quantitative determination of sewages, etc., I think comparative tests should be instituted setting forth results obtained with the raw liquors in question and with the well-settled liquors obtained from the same. One could then judge to some extent as to the impurity brought down to a sewage works by the adventitious addition of suspended matter, such as in the time of a storm. With regard to the character of the tests themselves, such as O. absorption from $KMnO_4$, and ammoniacal and albuminoid N., I think they give one a good idea as to the strength of sewage, etc.

22493. Then taking Question 22404, have you made actual observations which show that your practice would not cause clogging by sending to them an excess of solids?—Not in the case of storms, especially when the greater part of the organic matter is allowed to settle out in the sedimentation tanks. I have used the ordinary beds in times of storm, and I find that no ill effects have resulted either as regards efficiency or capacity.

22493*. When you answer the question, you are speaking from actual experience?—From actual experience, yes.

22494. On Question 22450, do you find that, say, a cubic yard of your shallowest bed is quite as efficient as a cubic yard of your deepest bed?—Yes, I find very little difference; of course, we do not work beyond 3¼ft. at Oldham.

22495. Of course, the difference is not large?—No.

22496. (*Sir William Ramsay.*) In answer to Question 22392, you refer to a black trade waste?—Yes.

22497. Does that ever clog the filter?—No, not to any serious extent; it is of a very thin nature, and the greater part of it is deposited in the tanks; but at the same time there is a great deal of impurity in solution, and that, I think, affects the filters adversely. This matter that is sent down is really used sewage. Certain millowners find it rather expensive to use town water, so at certain periods of the night they impound the weak sewage that comes down, and use it in their mill lodges; after an amount of straining and sedimentation it is then used for the boilers and condensers. After a time, the matter which has settled out in the tanks is sent down the sewers, especially on Saturdays and during holiday times. It may not have been originally black matter; I fancy it is really settled from solution in the sewage that has been impounded in these reservoirs, but it is a very evil smelling liquid.

22498. And very difficult to treat?—Yes.

22499. It would not be possible to get them to turn it out regularly, would it?—I think my committee are trying to put a stop to this practice, and there is less now coming down than, say, three or four years back.

22500. In answer to Question 22403, you spoke of the difficulty evinced by the filters in dealing with the first part of settled storm sewage?—Yes.

22501. Have you got it in figures?—Yes, lower down in the answer.

22502. These are the figures which deal with that?—I have additional examples which I can hand in.

22503. Of the same nature?—Of the same nature, yes, extending over a longer time.

22504. I do not think it is necessary. Towards the end of the answer to Question 22404, you speak of finely-divided matter in the Oldham sewage which remains in suspension even after twelve hours' standing. Is that exceptional, or does it hold in any other towns?—I should think it is exceptional. The Borough Surveyor's department, when the streets are finished, use the fine ashes from the mills; of course, that is from the coal; the coals contain a great amount of iron matter, and this becomes chiefly oxide of iron when burnt.

22505. This is chiefly that matter?—Yes.

22506. At the end of your answer to Question 22408, you say that the filters work better if occasionally filled with settled or precipitated dilute sewage, as will happen if a combined system of sewerage is used Do you find that the bacterial action becomes less strong, and it requires to be renewed?—I do not find it so far as my experience goes; it seems to me that in summer time after a storm, when the filters have received this weak sewage, and we get the almost immediate subsequent dry weather flow, then under those conditions, perhaps, the filters will not work efficiently.

22507. They have been washed out?—Yes, and the transition is too sudden, whereas in ordinary winter weather, where the transition is gradual, say from a wet weather flow to a dry weather flow, during the filtration of storm water the filters seem to benefit by this process.

22508. How often do you clear your tanks of sludge?—Well, the time is very variable; it depends upon circumstances.

22509. Upon the time of year?—Upon the time of year chiefly and the number of tanks we have in use. For example, in the summer time we very seldom use more than six tanks; at present I am using nine tanks, although very likely if this warm weather continues I shall reduce it down to perhaps six or seven.

22510. Could you give us some idea how often you clean them out?—I should say any time between six weeks and three months.

22511. Do you clean them completely?—Yes. Of course, this particular part of the works, that is, the cleansing of the tanks, is not under my control.

22512. In answer to Question 22417, you say you have no complaints from the treatment of sewage in settlement tanks. Are there many houses near?—Not so many, but I think it is a district that will gradually be built upon. I think it is likely we shall have two or three mills in the neighbourhood soon. There are certainly no smells. The only smell I notice is occasionally from the detritus pits at the end of the sewer where it empties into the works.

22513. In answer to the next question, 22419, you say that a sewage treated reasonably with precipitants, taking special care not to add any excess of lime, is more easily purified by subsequent filtration than the same sewage subjected to settlement only. Is that

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because the settlement is better when it is treated in this way than it would be otherwise?—I think the precipitants have a tendency to take down the very finely-divided suspended matter which cannot settle by sedimentation alone. At the same time matter in solution is precipitated, the quantity probably depending upon the amount of chemicals used.

22514. And you agree that the solid matter in the sewage is the difficulty in the way of purification?—Yes, to a great extent.

22515. And when that is got rid of it is very much more easily purified?—Yes, it is more easily purified.

22516. And you think that by precipitation you get rid of more solids than by mere sedimentation?—Then by mere sedimentation. Of course, we are not talking now of any septic action.

22517. No, no, merely precipitation?—Yes.

22518. Then let me refer you to your answer to Question 22442. About the middle of your answer you have a heading "(b)"; the tank effluent is in a better condition for subsequent treatment—that is, the organic impurities are in a simpler condition than when they are passed through settling tanks, and therefore fewer difficulties lie in the way of purification by contact or continuous treatment. Have you analytical reasons to give for that; have you examined the question, or is it merely an opinion?—It is chiefly my opinion, but, I have seen the thing in operation in Manchester. I was there for two years under Dr. Fowler, and, also judging from one or two experiments I have made as to the rate of flow through the tanks, I should think that the sewage is more equably mixed with a large tank capacity—that is, a capacity which would also conduce to a septic action.

22519. Oh, I see; that is to say, to produce septic action it requires a large tank and a long stay in it, and the sewage is more average when it remains a long stay?—Yes.

22520. You say a little further down that a septic tank effluent contains three to four parts in 100,000 excess in solution over a settled sewage effluent. That would corroborate that point?—Yes, I have done that by experiment.

22521. Over how long a period?—Well, those experiments were in 1903.

22522. But for how long?—Oh, extending perhaps over two or three months.

22523. At the end of your answer to Question 22481, you say that with a percolating filter there seems to be a limit, very soon reached, beyond which it is impossible to put any more liquid upon it in a given time. Is that again a matter of experience?—Only from casual observation.

22524. You have had no practical experience?—I have had no practical experience of my own. I have been to works where I have seen the thing in operation, and I have formed an opinion upon it.

22524*. In answer to Question 22486, are there any other remarks you would like to make upon the aeration test; you merely answer, "Yes, you have tried it." Do you think it is a good plan, the rate at which dissolved oxygen is taken up by the effluent; is it your common method of determining the strength of an effluent?—No, our method is the four hours' permanganate test.

22525. You do not use this?—Oh, I did for two years use, for the purposes of the Commission, this.

22526. What do you think it does; how do you think it compares?—Well, we get a greater quantity of oxygen taken up by the liquids, but the ratio is about the same. I think the ratios between the sewage, tank effluent, and the filtrate for the four hours' permanganate are about the same as the ratio with the dissolved oxygen, only the figures of the dissolved oxygen are higher.

22527. You think the permanganate test is easier to apply?—Oh, I should think so, especially for a man with no chemical training.

22528. Your figures for dissolved oxygen absorption against four hours' permanganate absorption are very much higher relatively?—Yes, that is what I have said just now.

22529. At what temperature do you do the dissolved oxygen absorption test?—I do it at the temperature of the air at the moment.

22530. Again, the test for nitrates. You say that, contrary to the general opinion, you find in your Oldham effluents that the amount of nitrate present has very little relation to the other tests, and it has but little influence on the incubator test?—Yes.

22531. Again, that is not generally supposed to be the case. It is found, I think, that when the dissolved oxygen disappears, then the nitrates come into play, and are drawn upon, and are reduced in amount. Do you not find that?—As a chemist it sounds reasonable to expect so, but I do not find it so. I have a tremendous number of effluents with but little nitrate in, and they keep perfectly sweet in an incubator, although the permanganate figure may be fairly high.

22532. (*Mr. Stafford.*) You speak of the strength of the sewage in Question 22396; you say that apart from Monday and Tuesday, and occasionally Wednesday, you are inclined to say that Oldham sewage might be classed as weak?—Yes.

22533. What standard have you applied to that to test whether it is weak or not?—Simply the appearance, the four hours' oxygen absorption, and the aptitude of the filters in dealing with the settled liquid.

22534. In answer to the same question a different answer is given by Mr. Wilkinson. He says, at Question 22589 in his evidence: The sewage would, I think, be best described as a strong domestic sewage." So it really turns upon what test you are both applying to the same sewage. One would really like to know what it is—what standard it is?—Well, as regards a purely domestic sewage, comparing it with other towns where the sewage is purely domestic, I would be inclined to call it strong, because we have a tremendous number of waste water-closets in operation.

22535. Yes, but you are both speaking of the same sewage. One describes it as strong, and the other as weak, and I want to know what standard you each have applied to it?—Well, we are accustomed to weak here; I am taking the four hours' oxygen absorption; I say on Thursdays and Fridays——

22536. But he is taking precisely the same days, apparently; he says, in answer to Question 22591, probably the number of grains of oxygen absorbed by the permanganate test is as good as any. You are both applying the same test, but you do not say how you arrive at the statement that the sewage is either "strong" or "weak"?—Perhaps it would be best to say it was strong in the earlier portion of the week, compared with the sewage of the latter portion of the week, or weak in the latter portion of the week as compared with that of the earlier portion, because then our filters have very little difficulty in dealing with this liquid. During the latter portion of the week one would naturally think it was a strong one (although I term it weak) because the fœcal matter is not washed down by a pure water, as it is, say, in Manchester, and other towns, but by the accumulation of the soapy matter in the slop closets.

22537. The domestic sewage may be strong, but when it is mixed with the trade refuse it may be weak?—Well, the strength, I think, is caused by the washing, the domestic washing on what I might term the wash-days, the clothes-washing days.

22538. (*Colonel Harding.*) Referring to storm waters, you tell us that storm water impurities are mainly in regard to the suspended matter contained in them?—Yes.

22539. But you say you come to the conclusion that, apart from the suspended matter, the first flow after dry weather is very polluting?—Yes.

22540. And you refer to certain matters going to solution?—Yes.

22541. What kind of experiments have you made?—Simply the experiments dealing only with the four hours' test. I have got a table here which I think proves that there seems to be a fair amount of impurity gathered in solution either from the roads or from the sewers when the first flush of storm water comes down.

22542. But the separation of suspended matter seems to bring about a great reduction of the impurities in all these samples given in your table?—Yes; but on comparing a filtered normal sewage with the filtered first flush of storm water sewage in Question 22403, you will find at 10 p.m. the filtered sewage, although the rate of flow was 14,000,000 gallons per 24 hours, was 1·42, while before the storm water came down the oxygen dissolved

was only 1·22, although the rate of flow of sewage was much less—2,800,000 gallons.

22543. Yes, but I do not think that quite substantiates what you say, does it, because you say that that largest figure that you give is practically the normal flow?—I don't see where my figures fail to substantiate my statement.

22544. And there the withdrawal of suspended matter brings about less than 50 per cent. improvement?—Oh, I am not talking about the comparative improvement; I am talking simply as to the filtered sewage itself, the liquid which goes on to the filters. There is no doubt that the great proportion of the additional impurity is caused by the suspended matter, but at the same time there is a small increment of impurity due to the dissolved matter, but in nothing like the same ratio.

22545. It does not appear to be very material except perhaps at the beginning of a storm. The main thing is the suspended matter?—Yes.

22546. Let me refer you to your answer to Question 22439. You say that at the beginning of the action of a septic tank you have comparatively little suspended matter coming out with the effluent, but as the accumulations increase in the tank in the later period of life of the tank you get much more?—Yes.

22547. And you say that is natural?—Yes.

22548. I suppose that is natural, because as the accumulations increase in the tank the capacity of the tank is reduced?—Yes.

22549. And therefore the flow becomes much more rapid?—Yes.

22550. Well, that is the answer one would naturally expect from you, but on Question 22441 you say there is very little difference in the amount of suspended matter caused by increasing the rate of flow up to twice or thrice the normal rate?—When only a small amount of sludge is in the tank; but no doubt there is a difference, but not so great as one would expect.

22551. But is not the amount of suspended matter brought away with the septic tanks largely in proportion to the rate of flow; and if you have an excessive rate of flow, does it not carry more off; there is less settlement, is there not?—I have only stated that with the proviso that there should be only a small amount of sludge in the tank.

22552. Take an empy tank, if you increase the quantity brought out?—Oh, it is bound to do that, but I say it will not make very much difference as the suspended matter coming down in the early portion of a storm is chiefly of a coarse nature. And not only that, you will find that a great deal of the suspended matter in Oldham sewage in times of storm is of such a nature that it will not settle.

22553. It is finely divided?—It is finely divided matter.

22554. If you increase the flow in a septic tank you are bound to increase the quantity coming out?—Yes, sir, under ordinary conditions of working, *i.e.*, under conditions where a great quantity of sludge is allowed to accumulate in the septic tanks.

22555. Your answer rather went to show that you did not think that. Now, in answer to Question No. 22442, the object of the question there was rather to find out whether two liquors being about equal in regard to suspended matter, the one coming from a septic tank and the other from mere settlement, unassisted by chemicals, whether the one would be easier to filter than the other. You have given us in your answer really a recapitulation of the advantages of septic tanks; you tell us you have septic tank effluent with a given amount of suspended matter, now have you a similar effluent not septicised?—Without precipitation.

22556. Without chemical assistance. For that matter you have three kinds, septic effluents, naturally settled sewage, and you have chemically precipitated sewage; and in all three cases you bring them down to the same amount of suspended matter, are you able from your experience to tell us whether the one would be more easy than the other to filter?—From my experience I should say the septic is more easy to treat.

22557. For the reasons you gave just now to Sir William Ramsay?—Yes.

22558. In 22411 you suggest that it might be advisable to use septic tanks in series for the purpose of reducing the amount of suspended matter coming out with the effluent?—Yes.

22559. Have you tried that?—This is simply a pious opinion.

22560. You have not based it upon any experiments of your own?—No.

22561. Would you not probably find that while that might be that result at first while your last tanks were comparatively new, but as sludge was deposited in the last tanks you would have the same conditions of movement in the suspended matter in the tank which causes it to come out in the effluents?—Well, if you had means of diverting the liquid from one tank into another tank, or of partially freeing these last tanks of their sludge, then this disadvantage would in all probability be reduced to a minimum.

22562. But you have no experience of your own of any arrangements for preventing suspended matter coming out with the effluent of septic tanks?—No.

22563. Your main experience at Oldham has been with contact beds?—Yes.

22564. And it has spread over how many years?—$2\frac{1}{2}$.

OLDHAM.

Appendix to Evidence of MR. A. H. VALENTINE.

Tables showing average analyses of sewage, tank liquor, and filter effluents at Oldham, January, 1903—December, 1904.

PROCESS OF TREATMENT:

Tanks and Single Contact Beds.

OLDHAM.

January, 1903.

SEWAGE—

Average daily flow	5,190,160 gallons	Total Rainfall	4·28 inches.
Maximum daily flow	13,579,000 „	Rainfall	·53 „
Minimum daily flow	2,084,000 „	Rainfall	nil.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (as NH_3)	·72	5·10	2·39
Albuminoid nitrogen	·32	1·51	·65
Nitric nitrogen (not done)	—	—	—
Chlorine	3·00	11·90	6·35
Grains per gallon oxygen absorbed from $KMnO_4$ in 4 hours	1·42	8·93	3·71
Dissolved oxygen taken up in 24 hours (not done as yet)	—	—	—
Suspended solids (1·8 samples)	Mineral. 3 / Volatile. 4	Mineral. 31 / Volatile. 73	Mineral. 15·2 / Volatile. 21·1

Number of samples analysed for the average = 31.

TANK LIQUOR—

Average daily flow through the tanks — 5,190,160 gallons.
Amount of sludge dealt with during month — 363⅕ tons (pressed sludge of about 50% moisture).

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (eight samples only)	·60	3·90	2·47
Albuminoid nitrogen („ „ „)	·18	·67	·475
Nitric nitrogen (not done)	—	—	—
Chlorine (occasionally done)	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	·61	4·16	2·37
Dissolved oxygen taken up in 24 hours (not done as yet)	—	—	—
Suspended solids (10 samples)	Mineral. 1 / Volatile. 3	Mineral. 6 / Volatile. 9	Mineral. 4·9 / Volatile. 5·2

Number of samples analysed for the average = 31 (for oxygen absorbed only).

FILTERS—

Amount of tank liquor treated on filters during the month	47,800,000 gallons (roughly calculated).
Average number of fillings per day	1.45
Rate of filtration in gallons per cube yard per 24 hours	·65

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·24	2·60	1·15
Albuminoid nitrogen	·09	·36	·17
Nitric nitrogen	1·23	·10	·49
Chlorine	3·5	8·0	5·40
Oxygen absorbed from $KMnO_4$ in 4 hours	·23 (Best individual filter.)	2·13 (Worst individual filter.)	·55
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (none done)	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.

Number of samples analysed for the average = 31.

REMARKS.—It should be noted that certain averages have been obtained approximately. Thus I may draw particular attention to " Rate of filtration in gallons," etc., and amount of tank liquor treated on filters. As regards average number of fillings per day, certain filters are filled twice per day, others (the more recent) once only. Dissolved oxygen tests will probably be commenced during April. I would suggest that suspended matter in sewage and tank effluent be obtained; also incubator tests for filters.

Laboratory, Foxdenton Lane, Hollinwood, Oldham. *A. H. Valentine, M.Sc. (Victoria).*
March 26th, 1903.

OLDHAM—*continued.*

February, 1903.

SEWAGE—

Average daily flow	5,883,000 gallons	Rainfall	·164 inches. (Total rainfall = 4.58 inches.)
Maximum daily flow	14,219,000 „	Rainfall	1·22 „
Minimum daily flow	2,684,000 „	Rainfall	none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·84	4·00	2·51
Albuminoid nitrogen	·30	·89	·60
Nitric nitrogen	—	—	—
Chlorine	2·60	13·60	6·64
Oxygen absorbed from $KMnO_4$ in 4 hours	1·69	6·01	3·49
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (18 samples)	Mineral. Volatile. 9 5	Mineral. Volatile. 39 30	Mineral. Volatile. 14·2 16·4

Number of samples analysed for the average = 28 (for oxygen absorption).

TANK LIQUOR—

Average daily flow through the tanks - - 5,883,000 gallons.
Amount of sludge dealt with during month - 512½ tons (50% solids)—not including lime.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·84	3·40	2·62 (8 expts.)
Albuminoid nitrogen	·26	·55	·44
Nitric nitrogen	—	—	—
Chlorine (not done)	—	—	—
Oxygen absorbed from KMnO in 4 hours	·62	4·44	2·337
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (8 samples)	Mineral. Volatile. 2 2	Mineral. Volatile. 9 3	Mineral. Volatile. 3·5 3·0

Number of samples analysed for the average = 28 (for oxygen absorption).

FILTERS—

Amount of tank liquor treated on filters during the month	45,080,000 gallons (approx.)
Average number of fillings per day	1·42
Rate of filtration in gallons per cube yard per 24 hours	67

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·32	2·20	1·116
Albuminoid nitrogen	·08	·28	·187
Nitric nitrogen	1·68	·09	·573
Chlorine	3·20	8·90	5·57
Oxygen absorbed from $KMnO_4$ in 4 hours	·10 (Best individual filter.)	1·80 (Worst individual filter.)	·52
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (none done)	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.

Number of samples analysed for the average = 28 (for oxygen absorption).

REMARKS.—All results are in grains per gallon. All tests in which N enter are expressed as NH_3. It should be noted that *two* average samples of tank liquor are analysed for oxygen absorption every working day, except Saturday, when the filters are only filled once. On Sunday a sample of tank liquor is also taken and eventually analysed. The *first* sample is the average tank liquor utilised for the *first* filling of the beds, etc. The daily average is the mean of these two samples. No time has as yet been found for dissolved oxygen experiments.

April 25th, 1903. *A. H. Valentine, M.Sc.* (Chemist).

OLDHAM—*continued.*

March, 1903.

SEWAGE—

Average daily flow	6,365,710 gallons	Rainfall	·177 inches.
Total	197,337,000 „	Total	5·49 „
Maximum daily flow	16,800,000 „	Rainfall	0·90 „
Minimum daily flow	2,402,090 „	Rainfall	none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·04	4·20	2·27
Albuminoid nitrogen	·34	·74	·55
Nitric nitrogen	—	—	—
Chlorine	3·10	11·90	5·91
Oxygen absorbed from $KMnO_4$ in 4 hours	2·05	8·77	3·24
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (14 samples)	Mineral. 9 Volatile. 7	Mineral. 18 Volatile. 20	Mineral. 11·5 Volatile. 13·8

Number of samples analysed for the average = 31.

TANK LIQUOR—

Average daily flow through the tanks - - - 6,365,710 gallons.
Amount of sludge dealt with during month - 524 tons pressed sludge (50% moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (14 only)	·72	3·40	2·34
Albuminoid nitrogen („)	·20	·58	·44
Nitric nitrogen	—	—	—
Chlorine (5 only)	3·10	9·20	5·78
Oxygen absorbed from $KMnO_4$ in 4 hours	·78	4·20	2·03
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (11 samples)	Mineral. 0 Volatile. 2	Mineral. 10 Volatile. 6	Mineral. 2·0 Volatile. 3·5

Number of samples analysed for the average = 31.

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 48,747,000 gallons (approximate).
Average number of fillings per day - - - 1·45 (taking 26 working days in month

$$\frac{\text{1,903 bed fillings}}{\text{26 days} \times \text{24 beds}} = 1.45.$$

Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 63⅓.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·26	2·15	·93
Albuminoid nitrogen	·085	·30	·17
Nitric nitrogen (as NH_3)	·46	·065	·19
Chlorine	2·00	9·10	4·93
Oxygen absorbed from $KMnO_4$ in 4 hours	·10 (Best individual filter)	1·82 (Worst individual filter)	·48
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (none done)	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.

Number of samples analysed for the average = 26.

REMARKS.—There is a great decrease in nitric nitrogen as compared with January and February. This may be due to the increased flow through the tanks, consequent upon the heavy rainfall, thus leading to a much less difference between the raw sewage and tank effluent than in drier months. Ammoniacal nitrogen and albuminoid nitrogen are reckoned as NH_3. An additional new bed has come into operation.

May 12th, 1903. *A. H. Valentine, M.Sc.* (Chemist.)

OLDHAM—*continued.*

April, 1903.

SEWAGE—

Average daily flow - - 3,613,133 gallons - Total rainfall - - - - 2·15 inches.
Total: 108,394,000 gallons.
Maximum daily flow - - 11,510,000 „ - Rainfall - - - - -
Minimum daily flow - - 1,669,000 „ - Rainfall - - - - - none.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (23 experiments) - - - -	1·36	3·40	2·58
Albuminoid nitrogen (23) - - - - - - -	·29	·77	·53
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine (28) - - - - - - - - - -	4·40	8·40	6·74
Oxygen absorbed from $KMnO_4$ in 4 hours (30) - -	1·48	8·00	3·65
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids (9) - - - - - - - -	Mineral. 0 Volatile. 10	Mineral. 24 Volatile. 58	Mineral. 13·1 Volatile. 22·4

Number of samples analysed for the average = 30 (for oxygen absorption).

TANK LIQUOR—

Average daily flow through the tanks - - - 3,613,133 gallons.
Amount of sludge dealt with during month - 506¼ tons (50% solids).

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (19 experiments) - - - -	·80	4·00	2·77
Albuminoid nitrogen (19) - - - - - - -	·21	·60	·47
Nitric nitrogen - - - - - - - - -	—	—	—
(Chlorine 27) - - - - - - - - - -	3·10	8·80	6·48
Oxygen absorbed from $KMnO_4$ in 4 hours (30) - -	·68	5·11	2·53
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids (9) - - - - - - - -	Mineral. 2 Volatile. 0	Mineral. 10 Volatile. 8	Mineral. 4·4 Volatile. 4·1

Number of samples analysed for the average = 30 (for oxygen absorption).

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 45,843,000 gallons.
Average number of fillings per day - - - 1·37 = 841 fillings ÷ (25 working days × 24½ beds).*
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 59½.

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (23 experiments) - - -	·28	2·35	1·31
Albuminoid nitrogen (23) - - - - - - -	·085	·36	·21
Nitric nitrogen (21) - - - - - - - -	·54	·065	·135
Chlorine (17) - - - - - - - - - -	4·20	8·60	6·36
Oxygen absorbed from $KMnO_4$ in 4 hours (25) - -	·16 (Best individual filter.)	2·07 (Worst individual filter.)	·705
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids (none done) - - - - - -	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.

Number of samples analysed for the average = 25 (for oxygen absorption).

REMARKS.—* There were 25 working days in the month, as the beds were not filled on Sundays and Good Friday. Bed "27" starts its first filling about the middle of the month; hence in obtaining average number of fillings per day, it is taken as ½. The two new beds, "26" and "27," although reckoned in estimating the amount filtered, the average number of fillings per day and the rate of filtration, are not included in the average analyses for final effluent. Dissolved oxygen experiments have been started towards the end of May.

June 9th, 1903. *A. H. Valentine, M.Sc.*

OLDHAM—*continued.*

May, 1903.

SEWAGE—

Average daily flow	5,179,000 gallons	Rainfall	0·133 inches.
Total	160,547,000 „	Total	4·13 „
Maximum daily flow	17,441,000 „	Rainfall	0·675 „
Minimum daily flow	1,568,000 „	Rainafll	none.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (22 tests)	·80	5·20	2·29
Albuminoid nitrogen (22)	·22	·93	·543
Nitric nitrogen	—	—	—
Chlorine (25)	2·80	10·70	6·33
Oxygen absorbed from $KMnO_4$ in 4 hours (31)	1·18	9·66	3·77
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (9)	Mineral. 3 / Volatile. 8	Mineral. 12 / Vo'atile. 60	Mineral. 12·9 / Volatile. 17·9

Number of samples analysed for the average = 31 (for oxygen absorption).

TANK LIQUOR—

Average daily flow through the tanks - - - 5,179,000 gallons.
Amount of sludge dealt with during month - 509 tons (50%).

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (12 tests)	·40	3·80	2·38
Albuminoid nitrogen (12)	·17	·72	·40
Nitric nitrogen	—	—	—
Chlorine (20)	2·80	9·10	6·30
Oxygen absorbed from $KMnO_4$ in 4 hours (31)	·63	4·61	2·38
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (6)	Mineral. 2 / Volatile. 4	Mineral. 8 / Volatile. 7	Mineral. 3·1 / Volatile 3·6

Number of samples analysed for the average = 31 (for oxygen absorption).

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - 58,845,000 gallons.
Average number of fillings per day - - - 1·43. = 1,012 fillings ÷ (26 working days × 26⅓* beds.)
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 68·9 = $\frac{58{,}845{,}000 \text{ gallons}}{32{,}828 \text{ cube yards} \times 26 \text{ working days}}$

* ⅓ indicates that a *new* bed was in use during the last third of the month.

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (26 tests)	·16	2·50	1·03
Albuminoid nitrogen (26)	·065	·35	·17
Nitric nitrogen, as NH_3 (72)	·26	·05	·088
Chlorine (26)	2·60	7·90	5·60
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	·06 (Best individual filter.)	2·77 (Worst individual filter.)	·691
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids (none done)	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.

Number of samples analysed for the average = 26 (for oxygen absorption).

REMARKS.—On May 4th, 5th, and 6th, days of heavy rainfall, various filters received storm water continuously for a few hours each day. I have reckoned, roughly, that under these conditions a bed would receive its own filling capacity each hour. This is included in the 1,012 fillings, and in the grand total of gallons filtered during the month.

June 25th, 1903. *A. H. Valentine, M.Sc.*

OLDHAM—*continued.*

June, 1903.

SEWAGE—

Average daily flow* (about) - 2,678,000 gallons - Rainfall - - - - - 2·50 inches.
Total (about) - - 80,340,000 ,,
Maximum daily flow* - - ,, - Rainfall - - - - - ·62 ,,
Minimum daily flow - - 1,478,000 ,, - Rainfall - - - - - none.

* Accident to gauge during one week in month.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (19 tests)	1·90	4·00	3·07
Albuminoid nitrogen (19)	·335	1·10	·641
Nitric nitrogen	—	—	—
Chlorine (21)	3·20	10·30	7·91
Oxygen absorbed from $KMnO_4$ in 4 hours (30)	3·12	8·82	4·95
Dissolved oxygen taken up in 24 hours (16)	2·149	7·042	4·38*
Suspended solids (9)	Mineral. 14 / Volatile. 11	Mineral. 37 / Volatile. 46	(Corresponding to Oxygen absorption of 5·74) Mineral. 19·6 / Volatile. 29·0

Number of samples analysed for the average (See numbers at side).

TANK LIQUOR—

Average daily flow through the tanks - - - About 2,678,000 gallons.
Amount of sludge dealt with during month - 441 tons (50%).

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (14 tests)	0·76	4·50	3·38
Albuminoid nitrogen (14)	·21	·58	·48
Nitric nitrogen	—	—	—
Chlorine (22)	2·70	9·80	7·66
Oxygen absorbed from $KMnO_4$ in 4 hours (44)	1·76	6·41	3·39
Dissolved oxygen taken up in 24 hours (16)	1·456	5·754	3·80*
Suspended solids	Mineral. 0 / Volatile. 4	Mineral. 6 / Volatile. 3	(Corresponding to Oxygen absorption of 3·7e) Mineral. 3·3 / Volatile. 3·3

Number of samples analysed for the average (See numbers at side).

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 44,700,000 gallons.
Average number of fillings per day - - - 1·135 = (797 fillings ÷ (27 filters × 26 workings days).
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - - 50·7

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (58 tests)	·38	2·75	1·56
Albuminoid nitrogen (58)	·085	·335	·226
Nitric nitrogen (reckoned as NH_3) (63)	·53	·055	·113
Chlorine (26)	3·60	9·70	7·33
Oxygen absorbed from $KMnO_4$ in 4 hours	·28 (Best individual filter.)	2·24 (Worst individual filter.)	1 2
Dissolved oxygen taken up in 24 hours (16)	·30	1·155	·804**
Suspended solids (none done)	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.

Number of samples analysed for the average = (See numbers at side).

REMARKS.—All numbers in grains per gallon. * The samples for dissolved oxygen were those from Monday, Tuesday, Wednesday, and Thursday. By reason of Sunday intervening, Friday and Saturday samples were not done. As Friday's and Saturday's sewage and tank liquor are generally weaker than the samples obtained from Monday to Thursday, the average oxygen absorption for these four days was obtained, and found to be for sewage 5·74, for tank 3·78. There is doubtless a corresponding increase in oxygen absorption for filters. The average number of fillings is being lowered on account of longer rests to the beds.

July 15th, 1903.

A. H. Valentine, M.Sc. (Chemist).

OLDHAM—*continued.*

July, 1903.

SEWAGE—

Average daily flow - - 3,734,774 gallons - Total rainfall - - - - 6·23 inches
(Total=115,778,000 gallons)
Maximum daily flow - - 8,427,000 „ - Rainfall - - - - - 1·28 „
Minimum daily flow - - 1,802,000 „ - Rainfall - - - - - none.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (18 experiments)	·52	3·40	2·56
Albuminoid nitrogen (18)	·375	·86	·60
Nitric nitrogen	—	—	—
Chlorine (27)	1·10	9·80	7·00
Oxygen absorbed from $KMnO_4$ in 4 hours (31)	1·97	7·36	3·98
Dissolved oxygen taken up in 24 hours (16)	2·303	5·705	3·96
Suspended solids (10)	Mineral. 4 / Volatile. 15	Mineral. 48 / Volatile. 22	Mineral. 19·0 / Volatile. 18·8

Number of samples analysed for the average (see above).

TANK LIQUOR—

Average daily flow through the tanks - - - 3,734,774 gallons.
Amount of sludge dealt with during month - - 414½ tons (50% moisture).

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (21 experiments)	1·60	4·20	3·07
Albuminoid nitrogen (21)	·31	·55	.45
Nitric nitrogen	—	—	—
Chlorine (29)	4·10	10·00	6·99
Oxygen absorbed from $KMnO_4$ in 4 hours (47)	1·31	4·94	2·925
Dissolved oxygen taken up in 24 hours (16)	1·134	5·488	3·02
Suspended solids (7)	Mineral. 4 / Volatile. 4	Mineral. 11 / Volatile. 6	Mineral. 5·1 / Volatile. 6·0

Number of samples analysed for the average (see above.)

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 50,586,000 gallons.
Average number of fillings per day - - - 1·18.=892 fillings÷(28 filters × 27 working days).
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 51⅔. (36,205 cubic yards).

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (24 experiments)	·24	2·30	1·23
Albuminoid nitrogen (24)	·058	·29	·183
Nitric nitrogen as NH_3 (22)	1·12	·08	·232
Chlorine (25)	3·50	9·10	6·50
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	·22 (Best individual filter.)	1·79 (Worst individual filter.)	·80
Dissolved oxygen taken up in 24 hours (16)	·259	1·883	·801
Suspended solids (none done)	Mineral. — / Volatile. —	Mineral. — / Volatile. —	Mineral. — / Volatile. —

Number of samples analysed for the average (see above).

REMARKS.—Dissolved oxygen experiments were done on 16 days only. The four hours oxygen absorption on these particular days were for sewage=4·13 ; tank effluent=3·02 ; filtrates=·79.

Another filter comes into operation.

During the middle of month Winkler's method for dissolved oxygen was substituted for Thresh's.

A small quantity of lime and copperas was added daily to sewage during the month.

Note.—As usual, all N. in form of NH_3.

August 12th, 1903. *A. H. Valentine, M.Sc.*

OLDHAM—*continued.*

Months, August and September, 1903.

SEWAGE—

			August.	September.
Average daily flow - - 5,720,360 gallons	-	Total rainfall -	7·56 inches.	7·69 inches.
Total: August, 173,811,000; September, 175,942,000.				
Maximum daily flow - -	-	Rainfall - - -	1·05 inches.	2·15 inches.
Minimum daily flow - -	-	Rainfall . .	none.	none.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (33 tests) - - - - - -	·64	4·30	2·15
Albuminoid nitrogen (33) - - - - - - -	·21	·84	·507
Nitric nitrogen - - - - - - - - - -	—	—	—
Chlorine (41) - - - - - - - - - -	2·60	11·70	6·41
Oxygen absorbed from $KMnO_4$ in 4 hours (43) - -	1·85	6·50	3·32*
Dissolved oxygen taken up in 24 hours (22) - -	1·575	7·819	4·65*
Suspended solids (10 for August) (8 for September) -	Aug. Min. Vol. 4 3 / Sept. Min. Vol. 4 10	Aug. Min. Vol. 100 35 / Sept. Min. Vol. 15 28	Aug. Min. Vol. 23·5 13·4 / Sept. Min. Vol. 10·7 13·9

* Corresponding 4 hours' oxygen absorption = 3·69. Best, 2·75; worst, 6.50.
Number of samples analysed for the average = 43 (for oxygen absorbed).

TANK LIQUOR—

Average daily flow through the tanks - - 5,720,360 gallons.
Amount of sludge dealt with during months - August, 390 tons; September, 494½ tons (about 50% moisture).

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (33 tests) - - - - - -	·76	3·70	2·40
Albuminoid nitrogen (33) - - - - - - -	·155	·55	·384
Nitric nitrogen - - - - - - - - - -	—	—	—
Chlorine (46) - - - - - - - - - -	1·90	9·30	6·26
Oxygen absorbed from $KMnO_4$ in 4 hours (69) - -	·61	4·72	2·42*
Dissolved oxygen taken up in 24 hours (22) - -	·616	6·517	3·607*
Suspended solids (5 for August) (3 for September) -	Aug. Min. Vol. 2 0 / Sept. Min. Vol 1 6	Aug. Min. Vol. 5 8 / Sept. Min. Vol. 3 8	Aug. Min. Vol. 3·0 7·2 / Sept. Min. Vol. 3·6 5·6

* Corresponding 4 hours' oxygen absorption from the $KMnO_4$ = 2·71. Best, 1·88; worst, 3·71.
Number of samples analysed for the average = 69 (for oxygen absorbed from $KMnO_4$).

FILTERS—

Amount of tank liquor treated on filters during the two months - - - - - - 153,250,000 gallons.
Average number of fillings per day - - 1·64.
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 79½.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (34 tests) - - - - -	·24	2·40	1·14
Albuminoid nitrogen (34) - - - - - - -	·08	·29	·17
Nitric nitrogen (106) - - - - - - - -	1·42	·09	·396
Chlorine (47) - - - - - - - - - -	2·20	9·00	6·05
Oxygen absorbed from $KMnO_4$ in 4 hours (38 averages) -	·16 (Best individual filter.)	2·10 (Worst individual filter.)	·654*
Dissolved oxygen taken up in 24 hours (22 averages) -	·315	1·743	·828*
Suspended solids (one only—storm water)- - - -	Mineral. Volatile. —	Mineral. Volatile. —	Mineral. Volatile. 4 3

* Corresponding 4 hours' oxygen absorption = ·757. Best, ·42; worst, 1·04.
Number of samples analysed for the average =

REMARKS.—During very heavy rainfalls, in order to relieve flow in the congested tank effluent carriers, certain of the filters have been used as continuous filters, thereby increasing "average number of fillings per day," "Rate of filtration in gallons per cube yard," etc.

All figures, as usual, in grains per gallon. All N as NH_3.

October 8th, 1903. *A. H. Valentine, M.Sc.*

OLDHAM—*continued.*

SEWAGE—

October, 1903.

Average daily flow - - 10,640,900 gallons - Total rainfall - - - - 12·34 inches
Total: 329,868,000 gallons.
Maximum daily flow - - 23,538,000 „ - Rainfall - - - - - 1·65 „
Minimum daily flow - - 3,942,000 „ - Rainfall - - - - - none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (28 experiments)	·31	2·80	1·39
Albuminoid nitrogen (28)	·19	·79	·368
Nitric nitrogen	—	—	—
Chlorine (33)	1·20	7·90	4·22
Oxygen absorbed from $KMnO_4$ in 4 hours (39)	·77	6·27	2·18
Dissolved oxygen taken up in 24 hours (16)	·225	7·05	2·29*
	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.
Suspended solids (11)	4 6	52 37	16·7 13·9

* Corresponding oxygen absorption from $KMnO_4$ = 2·54.

Number of samples analysed for the average = (See above).

TANK LIQUOR—

Average daily flow through the tanks - - - -
Amount of sludge dealt with during month - - - 395 tons (about 50% moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (26 experiments)	·32	2·60	1·25
Albuminoid nitrogen (26)	·12	·50	·272
Nitric nitrogen	—	—	—
Chlorine (44)	1·30	7·40	3·86
Oxygen absorbed from $KMnO_4$ in 4 hours (54)	·39	3·68	1·48
Dissolved oxygen taken up in 24 hours (16)	—	3·29	1·44*
	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.
Suspended solids (5)	3 4	9	9 6·8

* Corresponding oxygen absorption from $KMnO_4$ = 1·56.

Number of samples analysed for the average = (See above).

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 80,500,000 gallons by usual filling; 44,000,000 gallons by continuous flow = 124½ millions.

Average number of fillings per day - - - 1·84, exclusive of times when certain filters have been run continuously as storm filters.

Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 80·4 by usual filling; 124·4 including continuous filtering of storm water.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (49 experiments)	·07	1·50	·58
Albuminoid nitrogen (49)	·055	·21	·112
Nitric nitrogen (95)	1·32	·12	·50
Chlorine (42)	2·00	5·70	3·63
Oxygen absorbed from $KMnO_4$ in 4 hours (27 averages)	·05 (Best individual filter.)	1·29 (Worst individual filter.)	·35
Dissolved oxygen taken up in 24 hours (16)	·077*	·88	·34†
	Mineral. Volatile.	Mineral. Volatile.	Mineral. Volatile.
Suspended solids (only two—storm water)	— —	— —	3·0 1·0

* An increase in dissolved oxygen. † Corresponding oxygen absorption from $KMnO_4$ = ·40.

Number of samples analysed for the average = (See above).

REMARKS.—During hours of very heavy storm a certain number of filters have been used as continuous storm filters. The filters have been well filled, and subsequently the exit valve has been so regulated that the bed remains constantly full. About 66 per cent. purification, from the oxygen absorbed from $KMnO_4$ in 4 hours, reckoning on storm tank effluent has been obtained. The analyses for storm sewage, storm tank effluent, and storm filtrate are for the most part included in the above figures. As usual, results are in grains per gallon, and N as NH_3.

November 16th, 1903. *A. H. Valentine, M.Sc.*

OLDHAM—*continued.*

SEWAGE— November, 1903.

Average daily flow	7,246,600 gallons	Total rainfall	5·17 inches.
Total	217,398,000 „	Average	0·172 „
Maximum daily flow	18,127,000 „	Rainfall	1·10 „
Minimum daily flow	2,828,000 „	Total rainfall	none.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (22 experiments)	·48	4·20	1·90
Albuminoid nitrogen (22)	·26	·80	·45
Nitric nitrogen	—	—	—
Chlorine (30)	1·90	9·10	4·76
Oxygen absorbed from $KMnO_4$ in 4 hours (30)	1·12	6·08	2·52
Dissolved oxygen taken up in 24 hours (15 averages)	·46	6·11	2·76*
Suspended solids (14)	Mineral. 1 Volatile. 4	Mineral. 21 Volatile. 48	Mineral. 11·9 Volatile. 14·0

* Corresponding oxygen absorption from $KMnO_4$ = 2·86.
Number of samples analysed for the average = (See above).

TANK LIQUOR—

Average daily flow through the tanks — 7,246,600 gallons.
Amount of sludge dealt with during month — 380½ tons (of about 50 % moisture).

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (23 experiments)	·64	3·30	1·81
Albuminoid nitrogen (23)	·165	·53	·348
Nitric nitrogen	—	—	—
Chlorine (48)	2·00	6·70	4·8
Oxygen absorbed from $KMnO_4$ in 4 hours (30 averages)	·50	3·41	1·65
Dissolved oxygen taken up in 24 hours (16 averages)	·45	3·43	1·81*
Suspended solids	Mineral. 5 Volatile. 5	Mineral. 16 Volatile. 4	Mineral. 8·2 Volatile. 4·4

* Corresponding oxygen absorption from $KMnO_4$ = 1·82.
Number of samples analysed for the average = (See above).

FILTERS—

Amount of tank liquor treated on filters during the month — About 88,700,000 gallons, which is inclusive of continuous flow on November 2nd.
Average number of fillings per day — 1·70 (not including Sundays, and exclusive of continuous flow during storm on November 2nd).
Rate of filtration in gallons per cube yard per 24 hours — 96½ (inclusive of continuous storm flow).

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (40 experiments)	·23	1·60	·876
Albuminoid nitrogen (40)	·07	·26	·14
Nitric nitrogen (74)	1·18	·09	·403
Chlorine (45)	2·20	6·20	4·67
Oxygen absorbed from $KMnO_4$ in 4 hours (25 averages)	·05 (Best individual filter.)	1·64 (Worst individual filter.)	·416
Dissolved oxygen taken up in 24 hours (16 averages)	·19	·80	·47*
Suspended solids (none done)	Mineral. — Volatile. —	Mineral. — Volatile. —	Mineral. — Volatile. —

* Corresponding oxygen absorption from $KMnO_4$ = ·48.
Number of samples analysed for the average = (See above).

REMARKS.—Results, as usual, in grains per gallon, and all N. as NH_3. A new filter, No. 28, has come into operation during the month (November 17th), but it is not included in any of the above results. A continuous flow through fourteen filters for twelve hours on November 2nd is included in all the above results, except "Average number of fillings per day." A percentage purification, reckoning from filtrate to tank effluent, of about 66% was obtained.

December 14th, 1903. *A. H. Valentine, M.Sc.*, Chemist.

OLDHAM—*continued.*

December, 1903, including January 1–3, 1904.

SEWAGE—

Average daily flow	4,504,030 gallons	Total Rainfall	2·56 inches.
Total	153,137,000 „	Average	·075 „
Maximum daily flow	11,514,000 „	Rainfall	0·63 „
Minimum daily flow	2,279,000 „	Rainfall	none.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (26 experiments)	1·04	5·00	2·88
Albuminoid nitrogen (26)	·265	1·15	·643
Nitric nitrogen	—	—	—
Chlorine (34)	3·40	10·0	6·55
Oxygen absorbed from $KMnO_4$ in 4 hours (34)	1·15	8·17	3·80
Dissolved oxygen taken up in 24 hours (17 averages)	1·316	10·584	5·158*
Suspended solids (11)	Mineral. 3 Volatile. 8	Mineral. 15 Volatile. 40	Mineral. 10·8 Volatile. 19.6

* Corresponding oxygen absorbed from $KMnO_4$ = 4·32.
Number of samples analysed for the average = (See above).

TANK LIQUOR—

Average daily flow through the tanks - - - 4,504,030 gallons.
Amount of sludge dealt with during month - 437½ tons approximately (of 50% moisture).

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (24 experiments)	1·02	4·40	2·73
Albuminoid nitrogen (24)	·21	·745	·457
Nitric nitrogen	—	—	—
Chlorine (53)	3·00	8·6	6·00
Oxygen absorbed from $KMnO_4$ in 4 hours (57)	·72	5·18	2·355
Dissolved oxygen taken up in 24 hours (17 averages)	1·246	7·00	3·59*
Suspended solids (6)	Mineral. 2 Volatile. 4	Mineral. 13 Volatile. 13	Mineral. 6·7 Volatile. 8·3

* Corresponding oxygen absorbed from $KMnO_4$ = 2·62.
Number of samples analysed for the average = (See above)

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 92,500,000 gallons approximate.
Average number of fillings per day - - - 1·63 (reckoning, as usual, 6 days per week).
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - $\frac{92{,}500{,}000}{29 \text{ (days)} \times 38{,}330 \text{ (cube yards)}} = 83\frac{1}{4}$ (about.)

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (38 experiments)	·50	2·80	1·46
Albuminoid nitrogen (38)	·07	·37	·208
Nitric nitrogen (72)	1·12	·08	·238
Chlorine (49)	3·30	8·00	5·61
Oxygen absorbed from $KMnO_4$ in 4 hours (29 averages)	·06	1·93	·618
Dissolved oxygen taken up in 24 hours (17 averages)	·042†	1·988	·832*
Suspended solids (none done)	Mineral. — Volatile. —	Mineral. — Volatile. —	Mineral. — Volatile. —

† Signifies an increase in dissolved oxygen, or its equivalent (nitrites, etc.).
* Corresponding oxygen absorbed from $KMnO_4$ = ·704.
Number of samples analysed for the average = (See above).

REMARKS.—As usual, all results in grains per gallon, and N. as NH_3. January 1st to 3rd is included for convenience in tabulating results.

January 20th, 1904. *A. H. Valentine, M.Sc.*, Chemist.

OLDHAM—*continued.*

January 4th to 31st, 1904.

SEWAGE—

Average daily flow	5,802,393 gallons	Total Rainfall	5·09 inches.
Total	162,467,000 „	Average	·182 „
Maximum daily flow	19,942,000 „	Rainfall	1·09 „
Minimum daily flow	2,269,000 „	Rainfall	none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (17 tests)	1·24	3·80	2·61
Albuminoid nitrogen	0·32	1·25	0·606
Nitric nitrogen	—	—	—
Chlorine	1·90	7·80	5·52
Oxygen absorbed from $KMnO_4$ in 4 hours (24)	1·36	11·36	3·89
Dissolved oxygen taken up in 24 hours (16)	0·742	11·935	5·413*
Suspended solids (11)	Mineral. 4 Volatile. 8	Mineral. 49 Volatile. 86	Mineral. 20·8 Volatile. 26·3

* Corresponding oxygen absorbed from $KMnO_4$ = 5·013.

Number of samples analysed for the average = (See above).

TANK LIQUOR—

Average rate of flow through the tanks - - 5,802,393 gallons.
Amount of sludge dealt with during the month - 444 tons (about 50% moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·04	4·40	2·78
Albuminoid nitrogen	0·24	0·66	0·452
Nitric nitrogen	—	—	—
Chlorine	1·80	8·50	5·62
Oxygen absorbed from $KMnO_4$ in 4 hours (24)	0·67	5·12	2·59
Dissolved oxygen taken up in 24 hours (16)	0·546	6·475	3·470*
Suspended solids (5)	Mineral. 4 Volatile. 1	Mineral. 5 Volatile. 13	Mineral. 4·2 Volatile. 8·0

* Corresponding oxygen absorbed from $KMnO_4$ = 3·004.

Number of samples analysed for the average = (See above).

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 80,600,000 gallons, approximate.
Average number of fillings per day - - - 1·75 (six working days per week).
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 91·3.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	0·46	2·70	1·39
Albuminoid nitrogen	0·075	0·38	0·203
Nitric nitrogen	1·42	0·07	0·241
Chlorine	2·40	7·60	5·19
Oxygen absorbed from $KMnO_4$ in 4 hours (24)	·00 (Best individual filter.)	2·33 (Worst individual filter.)	0·586
Dissolved oxygen taken up in 24 hours (16)	0·196	1·414	0·705*
Suspended solids (one only)	Mineral. — Volatile. —	Mineral. — Volatile. —	Mineral. 0 Volatile. 1

* Corresponding oxygen absorbed from $KMnO_4$ = 0·712.

Number of samples analysed for the average =

REMARKS.—All results, as usual, in grains per gallon, and N. as NH_3. All experiments are from January 4th to January 31st inclusive, except amount of sludge pressed, which is quantity for the entire calendar month. In the report for December, 1903, please note that sludge pressed is also for the calendar month.

February 16th, 1904. *A. H. Valentine, M.Sc.*, Chemist.

OLDHAM—*continued.*

February, 1904.

SEWAGE—

Average daily flow - - 8,272,448 gallons - Total Rainfall - - - - 4·50 inches.
Total: 239,901,000 gallons. Average: 0·155 inches.
Maximum daily flow - - 19,595,000 „ - Rainfall - - - - - 0·85 „
Minimum daily flow - - 3,710,000 „ - Rainfall - - - - - none.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (25 experiments) - - -	0·76	2·80	1·91
Albuminoid nitrogen (25) - - - - - - -	0·23	0·72	0·461
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine (31) - - - - - - - - - -	2·20	8·60*	5·01
Oxygen absorbed from $KMnO_4$ in 4 hours (31) - - -	1·06	4·21	2·55
Dissolved oxygen taken up in 24 hours (17) - - -	1·099	5·103	3·028†
Suspended solids (6) - - - - - - - -	Mineral. 5 Volatile. 5	Mineral. 12 Volatile. 15	Mineral. 8·6 Volatile. 9·3

* Due to salt melting snow in town. † Corresponding oxygen absorbed from $KMnO_4$ = 2·95.
Number of samples analysed for the average = (See above.)

TANK LIQUOR—

Average daily flow through the tanks - - - - ——
Amount of sludge dealt with during month - - - 425 tons, (about 50% moisture).

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (22) - - - - - - -	0·68	3·10	1·80
Albuminoid nitrogen (22) - - - - - - -	0·165	0·695	0·362
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine (48) - - - - - - - - - -	2·10	7·30*	4·72
Oxygen absorbed from $KMnO_4$ in 4 hours (50) - - -	0·55	3·43	1·81
Dissolved oxygen taken up in 24 hours (17) - - -	0·427	3·500	2·181†
Suspended solids (8) - - - - - - - -	Mineral. 3 Volatile. 3	Mineral. 9 Volatile. 6	Mineral. 5·2 Volatile 4·2

* Due to salt melting snow in town. † Corresponding oxygen absorbed from $KMnO_4$ = 1·93.
Number of samples analysed for the average = (See above.)

FILTERS—

Amount of tank liquor treated on filters during the month - - - - - - - - 81,000,000 gallons (not including storm water treated an additional 25,000,000).
Average number of fillings per day - - - 1·75 (not including storm water) (6 working days).
Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - 88¼ (not including storm water).

Average Analysis of Final Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen (33) - - - - - - -	0·20	1·90	0·984
Albuminoid nitrogen (33) - - - - - - -	0·072	0·23	0·155
Nitric nitrogen (72) - - - - - - - -	1·840	0·10	0·457
Chlorine (45) - - - - - - - - - -	2·60	10·30*	4·550
Oxygen absorbed from $KMnO_4$ in 4 hours (25 daily averages) - - - - - - - - -	0·05 (Best individual filter.)	1·25 (Worst individual filter.)	0·417
Dissolved oxygen taken up in 24 hours (17) - - -	0·049†	0·658	0·431‡
Suspended solids (3) - - - - - - - -	Mineral. 1 Volatile. 0	Mineral. 4 Volatile. 1	Mineral. 1·7 Volatile. 0·7

* Due to salt melting snow in town. † Signifies an increase in dissolved oxygen. ‡ Corresponding Oxygen absorbed from $KMnO_4$ = 0·517.
Number of samples analysed for the average = (See above).

REMARKS.—As usual, all N. are expressed as NH_3, and all results as grains per gallon. All the above analytical numbers *include* storm sewage, tank effluent and filtrate. At a *very rough* guess and calculation, about 25,000,000 gallons were sent continually through the filters on February 4th and 8th—days of excessive flow. Filter 28, the newest filter, was compulsorily stopped during the month on account of constructional work in connection therewith. Its cubic capacity is, therefore, *not* in above, in order to obtain "average number of fillings," and "rate of filtration."

March 12th, 1904. *A. H Valentine, M.Sc.*

OLDHAM—*continued.*

March and April, 1904.

SEWAGE—

	March.	April.		March.	April.
Average daily flow	5,198,129 gals.	4,676,200 gals.	-	Total rainfall 2·50 inches.	1·46 inches.
Total, March =	161,142,000 „				
Total, April =	140,286,000 „				
Maximum daily flow	13,799,000 „	8,871,000 „	-	Rainfall - 0·58 „	0·58 „
Minimum daily flow	2,238,000 „	2,146,000 „		Rainfall - none.	none.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (34 experiments) - - -	1·04	3·50	2·67
Albuminoid nitrogen (34) - - - - - - -	0·385	1·01	0·622
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine (54) - - - - - - - - -	3·0	10·5	6·00
Oxygen absorbed from $KMnO_4$ in 4 hours (52) - -	1·65	11·31	3·83
Dissolved oxygen taken up in 24 hours (24) - - -	1·911	10·976	5·174*
Suspended solids (10) - - - - - - - -	Mineral. Volatile. 8 7	Mineral. Volatile. 13 55	Mineral. Volatile. 10·0 16·0

* Corresponding oxygen absorption, 4 hours from $KMnO_4$ = 4·476.
Number of samples analysed for the average = (See above).

TANK LIQUOR—

Average rate of flow through the tanks - - (See above.)

	March.	April.
Amount of sludge dealt with during the month -	About 505 tons.	About 612 tons (50% moisture).

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (32 experiments) - - -	1·20	3·80	2·66
Albuminoid nitrogen (32) - - - - - -	0·23	0·725	0·485
Nitric nitrogen - - - - - - - - -	—	—	—
Chlorine (98) - - - - - - - - -	3·0	8·7	5·83
Oxygen absorbed from $KMnO_4$ in 4 hours (88) - - -	0·82	6·02	2·79
Dissolved oxygen taken up in 24 hours (24) - - -	1·064	7·714	4·044*
Suspended solids (5) - - - - - - - -	Mineral. Volatile. 2 6	Mineral. Volatile. 8 5	Mineral. Volatile. 5·8 5·6.

* Corresponding oxygen absorption, 4 hours from $KMnO_4$ = 3·125.
Number of samples analysed for the average = (See above).

FILTERS—

Amount of tank liquor treated on filters during the months - - - - - - - - - 172,800,000 gallons (exclusive of storm water filtered, and not including the quantity on filter 28, which has been compulsorily idle the greater part of time owing to constructional work).

Average number of fillings per day - - - 1·80 (six days per week).

Rate of filtration in gallons per cube yard per 24 hours - - - - - - - - - 90 (an allowance has been made for a new filter, No. 29, which commenced work on March 21st):

$$= \frac{172{,}800{,}000}{36275 \times 53}$$

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (54 experiments) - - - -	0·40	2·50	1·28
Albuminoid nitrogen (54) - - - - - -	0·085	0·335	0·19
Nitric nitrogen (110) - - - - - - - -	1·14	0·08	0·361
Chlorine (79) - - - - - - - - - -	3·30	7·30	5·39
Oxygen absorbed from $KMnO_4$ in 4 hours (53 daily averages)	0·11 (Best individual filter.)	3·03 (Worst individual filter.)	0·67
Dissolved oxygen taken up in 24 hours (24) - - -	0·168	1·680	0·86*
Suspended solids (only one—storm water) - - -	Mineral. Volatile. — —	Mineral. Volatile. — —	Mineral. Volatile. 8 3

* Corresponding oxygen absorption, 4 hours from $KMnO_4$ = 0·80.
Number of samples analysed for the average = (See above).

REMARKS.—All filters were filled twice per day during the two months, except on Saturdays, when, as has been the case always at these works, the filters were only filled once. On Sundays all the filters rest.

On March 14th, filters 1–27 were running continuously for 13 hours ; on April 15th, filters 1–22 were running continuously for six hours ; on April 22nd, filters 1–27 were running continuously for seven hours—about 14 gallons sent through.

All results in grains per gallon, and N. as NH_3.

May 10th, 1904. *A. H. Valentine, M.Sc.*, Chemist.

OLDHAM—*continued.*

SEWAGE—

				May, 1904.
Average daily flow	3,816,580 gallons	Total rainfall		3·82
Total	118,314,000 „	Average		·123
Maximum daily flow	10,578,000 „	Rainfall		·75
Minimum daily flow	2,116,000 „	Rainfall		·01

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (23 experiments)	1·60	3·70	2·91
Albuminoid nitrogen (23)	0·385	0·96	0·686
Nitric nitrogen			
Chlorine (30)	4·40	12·30	6·90
Oxygen absorbed from $KMnO_4$ in 4 hours (31)	0·96	8·43	4·33
Dissolved oxygen taken up in 24 hours (16)	2·877	12·446	7·754*
Suspended solids (7)	Mineral. 10 Volatile. 12	Mineral. 18 Volatile. 38	Mineral. 12·7 Volatile. 21·4

* Corresponding oxygen absorption 4 hours from $KMnO_4$ = 4·99.
Number of samples analysed for the average =

TANK LIQUOR—
Average rate of flow through the tanks. (*See* above.)
Amount of sludge dealt with during the month, 544 tons (about 50% moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (22 experiments)	1·40	4·00	3·28
Albuminoid nitrogen (22)	0·23	0·65	0·522
Nitric nitrogen			
Chlorine (47)	2·50	9·00	6·52
Oxygen absorbed from $KMnO_4$ in 4 hours (50)	0·79	7·00	3·09
Dissolved oxygen taken up in 24 hours (16)	3·458	9·233	5·95*
Suspended solids (4)	Mineral. 3 Volatile. 6	Mineral. 14 Volatile. 4	Mineral. 7·2 Volatile. 6·0

* Corresponding oxygen absorption 4 hours four $KMnO_4$ = 3·552.
Number of samples analysed for the average =

FILTERS—
Amount of tank liquor treated on filters during the month, 74,578,000 gallons.
Average number of fillings per day, 1·57 = $\frac{1244 \text{ bed fillings}}{26 \text{ working days} \times 30\frac{1}{2} \text{ beds}}$ (No. 28 bed taken as $\frac{1}{2}$, as it was compulsorily resting $\frac{1}{2}$ the month).
Rate of filtration in gallons per cube yard per 24 hours, 78·5 +

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (37 experiments)	0·36	2 80	1·595
Albuminoid nitrogen (37)	0·095	0·36	0·241
Nitric Nitrogen (67)	0·53	0·09	0·225
Chlorine (44)	3·00	8·10	6·13
Oxygen absorbed from $KMnO_4$ in 4 hours (26 daily aver.)	0·23 (Best individual filter.)	2·15 (Worst individual filter.)	0·855
Dissolved oxygen taken up in 24 hours (16)	0·63	2·198	1·270*
Suspended solids (2)	Mineral. 0 Volatile. 0	Mineral. 0 Volatile. 1	Mineral. 0 Volatile. $\frac{1}{2}$

* Corresponding oxygen absorption 4 hours $KMnO_4$ = 0·984.
Number of samples analysed for the average =

REMARKS.—It should be noted that in the "average analysis of final effluent oxygen absorbed from $KMnO_4$ in 4 hours," between 15–24 analyses are done daily ; therefore 26 × (15 to 24) analyses are done during the month.
All results in terms as heretofore.

A. H. Valentine, M.Sc. (Chemist).

June 13th, 1904.

OLDHAM.

June, 1904.

SEWAGE—

Average daily flow - - 2,897,967 gallons.
Total - - - - 86,939,000 „
Maximum daily flow - - 7,068,000 „
Minimum daily flow - - 1,658,000 „

Total rainfall - - - 1·79 inches.
Rainfall - - - - 0·75 „
Rainfall - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (24 experiments) - - -	2·20	3·80	3·23
Albuminoid nitrogen „ - - - - -	0·505	1·15	0·750
Nitric nitrogen - - - - - - - - - -	—	—	—
Chlorine (30) - - - - - - - - - -	5·40	14·70	7·78
Oxygen absorbed from $KMnO_4$ in 4 hours (26) - - -	2·62	9·60	4·75+
Dissolved oxygen taken up in 24 hours (17) - - -	3·745	13·825	9 887*
Suspended solids (9) - - - - - - - - -	Mineral. 5 Volatile. 9	Mineral. 43 Volatile. 33	Mineral. 17·2 Volatile. 23·4

* Corresponding oxygen absorbed from $KMnO_4$ (4 hours) = 5·143.
Number of samples analysed for the average =

TANK LIQUOR—

Average rate of flow through the tanks - - 2,897,967 gallons.
Amount of sludge dealt with during the month - about 482½ tons (about 50% moisture).

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (24 experiments) - - - -	1·80	4·40	3·50
Albuminoid nitrogen „ - - - - -	0·36	0·77	0·557
Nitric nitrogen - - - - - - - - - -	—	—	—
Chlorine (47) - - - - - - - - - -	2·60	8·90	7·61
Oxygen absorbed from $KMnO_4$ in 4 hours (47) - - -	0·68	5·29	3·32+
Dissolved oxygen taken up in 24 hours (17) - - -	1·652	11·662	7·935*
Suspended solids (5) - - - - - - - - -	Mineral. 1 Volatile. 4	Mineral. 9 Volati'e- 10	Mineral. 6·8 Volatile. 6·8

* Corresponding oxygen absorbed from $KMnO_4$ (4 hours) = 3·522.
Number of samples analysed for the average =

FILTERS—

Amount of tank liquor treated on Filters during the month - - 62,500,000 gallons.
Average number of fillings per day - - - - - 1·403 (6 days per week).
Rate of filtration in gallons per cube yard per 24 hours - - 62·5 +

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (42 experiments) - - - -	0·32	2·60	1·76
Albuminoid nitrogen „ - - - -	0·09	0·41	0·27
Nitric nitrogen (82) - - - - - - - - -	+4·00	0·06	0·24
Chlorine (43) - - - - - - - - - -	3·10	8·20	6·95
Oxygen absorbed from $KMnO_4$ in 4 hours (26 averages)	0·54 as daily average.	1·46	0·977
Dissolved oxygen taken up in 24 hours (17) - - -	0·637	2·583	1·589*
Suspended solids (3) - - - - - - - -	Mineral. 0 Volatile. 1	Mineral. 1·5 Volatile. 1·5	Mineral. 1 Volatile. 1·3

+Certain group of filters after resting 1½ weeks.
* Corresponding oxygen absorbed from $KMnO_4$ (4 hours) = 1·053.
Number of samples analysed for the average =

REMARKS.—All results in terms as usual.

July 19th, 1904.

A. H. Valentine, M.Sc. (Chemist).

OLDHAM—*continued.*

July, 1904.

SEWAGE—

Average daily flow	2,659,452 gallons	Total Rainfall	1·42 inches.
Total	82,443,000 „	Average	0·0458 „
Maximum daily flow	4,881,000 „	Rainfall	0·36 „
Minimum daily flow	1,525,000 „	Rainfall	none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (23 experiments)	2·50	4·00	3·452
Albuminoid nitrogen (23)	0·60	3·25	0·976
Nitric nitrogen	—	—	—
Chlorine (31)	5·60	10·30	7·842
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	3·48	15·58	5·719
Dissolved oxygen taken up in 24 hours (16)	6·769	18·200	11·495*
Suspended solids (6)	Mineral. Volatile. 11 14	Mineral. Volatile. 51 81	Mineral. Volatile. 24·8 35·1

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 6·483.

Number of samples analysed for the average =

TANK LIQUOR—

Average rate of flow through the tanks - 2,659,442 gallons.
Amount of sludge dealt with during the month - about 396 tons (50 °/₀ moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (21 experiments)	2·70	4·70	3·948
Albuminoid nitrogen (21)	0·46	0·72	0·590
Nitric nitrogen	—	—	—
Chloride (41)	4·50	9·80	8·110
Oxygen absorbed from $KMnO_4$ in 4 hours (45)	2·55	5·67	3·916
Dissolved oxygen taken up in 24 hours (16)	5·754	11·718	9·290*
Suspended solids (6)	Mineral. Volatile. 6 7	Mineral. Volatile. 13 21	Mineral. Volatile. 8·6 10·1

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 4·021.

Number of samples analysed for the average =

FILTERS—

Amount of tank liquor treated on filters during the month - 61,615,000 gallons.
Average number of fillings per day - 1·188.
Rate of filtration in gallons per cube yard per 24 hours - 57·5+

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (37 experiments)	1·15	2·95	1·795
Albuminoid nitrogen (37)	0·185	0·36	0·281
Nitric nitrogen (72) (NH_2)	+ 1·450	0·06	0·210
Chloride (42)	4·40	8·70	7·414
Oxygen absorbed from $KMnO_4$ in 4 hours (26 daily averages)	0·785 (As daily average.)	1·598 (As daily average.)	1·154
Dissolved oxygen taken up in 24 hours (16)	1·148	3·402	2·069*
Suspended solids (2)	Mineral. Volatile. 1 4	Mineral. Volatile. 3 4	Mineral. Volatile. 2 4

\+ After 1½ weeks' rest; the highest for filters working regularly = 0·92.

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 1·258.

REMARKS.—A new filter came into operation on July 1st. A certain number of filters were compulsorily stopped for some days owing to constructional work on a tank effluent carrier, otherwise "the average number of fillings per day," etc., would have been nearly the same as for June. On July 21st chemical treatment with milk of lime and copperas solution was started on account of the strength of the sewage. All results in grains per gallon.

August 17th, 1904.

A. H. Valentine M.Sc. (Chemist).

OLDHAM—*continued.*

August, 1904.

SEWAGE—

Average daily flow	4,821,420 gallons	Total Rainfall	6·01 inches (?)
Total	149,464,000 „		—
Maximum daily flow	24,442,000 „	Rainfall (August 22)	1·05 inches (?)
Minimum daily flow	1,401,000 „	Rainfall	none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (17 experiments)	·76	4·40	2·85
Albuminoid nitrogen (17)	·33	1·20	·708
Nitric nitrogen	—	—	—
Chlorine (31)	2·90	9·60	6·79
Oxygen absorbed from $KMnO_4$ in 4 hours (27)	2·46	9·03	4·273
Dissolved oxygen taken up in 24 hours (16)	1·638	15·374	7·896 *
Suspended solids (8)	Mineral. 11 / Volatile. 14	Mineral. 29 / Volatile. 22	Mineral. 18·7 / Volatile 20·0

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 4·664.

Number of samples analysed for the average= .

TANK LIQUOR—

Average rate of flow through the tanks - - - - (*See* above.)
Amount of pressed sludge dealt with during the month - About 382 tons of 50 % moisture.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (18 experiments)	·68	4·40	2·76
Albuminoid nitrogen (18)	·23	·65	·452
Nitric nitrogen	—	—	—
Chlorine (50)	1·60	10·40	6·546
Oxygen absorbed from $KMnO_4$ in 4 hours (48)	·68	4·96	2·71
Dissolved oxygen taken up in 24 hours (16)	·812	9·240	5·18 7*
Suspended solids (6)	Mineral. 5 / Volatile. 4	Mineral. 15 / Volatile. 6	Mineral. 7·3 / Volatile. 5·6

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 2·814.

Number of samples analysed for the average= .

FILTERS—

Amount of tank liquor treated on filters during the month - 78,200,000 gallons.
Average number of fillings per day - - - - - 1·47.
Rate of filtration in gallons per cube yard per 24 hours - - 70·6.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (29 experiments)	·27	2·50	1·28
Albuminoid nitrogen (29)	·075	·335	·214
Nitric nitrogen as NH_3	·92	·08	·172
Chlorine (46)	2·60	9·40	5·99
Oxygen absorbed from $KMnO_4$ in 4 hours (27 daily averages)	·40 (As daily average.)	1·470 (As daily average.)	·808
Dissolved oxygen taken up in 24 hours (16)	·273	2·975	1·382*
Suspended solids (3)	Mineral. 3 / Volatile. 1	Mineral. 5 / Volatile. 4	Mineral. 3·7 / Volatile. 2·0

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 0·888.

Number of samples analysed for the average= .

REMARKS.—All results in grain per gallon. The above rainfall is probably an inch lower than the actual quantity collected. On August 22nd, a generally wet day throughout the country, the measuring glass broke, though on inspection on the morning of August 23rd, there was 1·05 inches in the portion remaining. Judging from the amount registered in Manchester, it is probable that there was a rainfall of 2 inches on August 22nd. There was continuous rain from 12.30 a.m., August 22nd, to 5 a.m., August 23rd The gauge measurements are taken at 10 a.m.

A. H. Valentine, M.Sc. (Chemist).

September 16th, 1904.

OLDHAM—*continued.*

September, 1904.

SEWAGE—

Average daily flow	2,975,066 gallons	Total Rainfall	2·43 inches.
Total	89,252,000 „	Average	0·081 „
Maximum daily flow	10,802,000 „	Rainfall	1·01 „
Maximum daily flow	1,509,000 „	Rainfall	none.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (18 experiments)	2·70	4·20	3·49
Albuminoid nitrogen (18)	0·62	2·30	0·908
Nitric nitrogen	—	—	—
Chlorine (30)	3·40	10·80	7·51
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	2·13	10·00	4·50
Dissolved oxygen taken up in 24 hours (16)	5·28	18·34	8·90*
Suspended solids (10)	Mineral. 6 / Volatile. 12	Mineral. 27 / Volatile. 65	Mineral. 13·0 / Volatile. 24·6

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 4·96.

Number of samples analysed for the average =

TANK LIQUOR—

Average rate of flow through the tanks - 2,975,066 gallons daily.
Amount of sludge dealt with during the month - about 438 tons pressed sludge of 50 % moisture.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (19 experiments)	2·60	4·80	3·87
Albuminoid nitrogen (19)	0·46	0·72	0·574
Nitric nitrogen	—	—	—
Chlorine (48)	2·40	9·80	7·723
Oxygen absorbed from $KMnO_4$ in 4 hours (48)	1·35	5·05	3·20
Dissolved oxygen taken up in 24 hours (16)	3·48	9·73	7·08*
Suspended solids (8)	Mineral. 7 / Volatile. 0	Mineral. 7 / Volatile. 9	Mineral. 5·6 / Volatile. 7·6

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 3·43.

Number of samples analysed for the average =

FILTERS—

Amount of tank liquor treated on filters during the month - 72,750,000 gallons.
Average number of fillings per day - 1·37.
Rate of filtration in gallons per cube yard per 24 hours - 68·2.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (31 experiments)	1·10	2·60	1·821
Albuminoid nitrogen (31)	0·18	0·32	0·265
Nitric nitrogen (NH_4) (74)	1·20	0·08	0·20
Chlorine (44)	4·00	9·20	7·23
Oxygen absorbed from $KMnO_4$ in 4 hours (26 daily averages)	0·14 (As daily average.)	1·39 (As daily average.)	0·949
Dissolved oxygen taken up in 24 hours (16)	0·735	2·121	1·380*
Suspended solids (7)	Mineral. 2 / Volatile. 1	Mineral. 3 / Volatile. 3	Mineral. 1·4 / Volatile. 3·3

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 1·03.

Number of samples analysed for the average =

REMARKS.—Chemicals (copperas and lime) were used on every Monday and Tuesday during the month, starting from 11.30 a.m. and continuing to 6.30 p.m. All results in grains per gallon.

October 11th, 1904. *A. H. Valentine, M.Sc.*

OLDHAM—*continued.*

October, 1904.

SEWAGE—

Average daily flow	3,805,580 gallons	Total Rainfall	2·97 inches
Total	117,973,000 „	Average	·096 „
Maximum daily flow	13,326,000 „	Rainfall	1·05 „
Minimum daily flow	1,741,000 „	Rainfall	none.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (32 experiments)	1·32	4·00	3·038
Albuminoid nitrogen (23)	0·425	1·34	0·747
Nitric nitrogen	—	—	—
Chlorine (31)	3·90	14·40	7·374
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	2·61	8·83	4·40
Dissolved oxygen taken up in 24 hours (17)	3·507	18·375	8·607*
Suspended solids (11)	Mineral. 5 / Volatile. 13	Mineral. 5 / Volatile. 38	Mineral. 9·4 / Volatile. 19·2

* Corresponding oxygen absorbed from $KMnO_4$, 4 hours = 5·00.
Number of samples analysed for the average =

TANK LIQUOR—

Average rate of flow through the tanks - - - - - - 3,805,580 gallons per 24 hours.
Amount of sludge dealt with during the month about - - - 360 tons (50 per cent. moisture).

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (32 experiments)	0·92	4·40	3·072
Albuminoid nitrogen (23)	0·23	0·67	0·515
Nitric nitrogen	—	—	—
Chlorine (49)	1·70	9·30	6·908
Oxygen absorbed from $KMnO_4$ in 4 hours (47)	1·42	5·25	2·978
Dissolved oxygen taken up in 24 hours (17)	2·562	9·394	6·572*
Suspended solids (10)	Mineral. 3 / Volatile. 5	Mineral. 7 / Volatile. 12	Mineral. 5·3 / Volatile. 7·7

* Corresponding oxygen absorbed from $KMnO_4$, 4 hours = 3·251.
Number of samples analysed for the average =

FILTERS—

Amount of tank liquor treated on filters during the month - - - 78,250,000 gallons.
Average number of fillings per day - - - - - - - - - 1·49.
Rate of filtration in gallons per cube yard per 24 hours - - - - 73⅓.

Average Analysis of Final Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen (38 experiments)	0·26	2·70	1·506
Albuminoid nitrogen (38)	0·09	0·39	0·241
Nitric nitrogen (70)	0·80	0·06	0·160
Chlorine (44)	2·60	8·60	6·409
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	0·28 (As daily average.)	1·345 (As daily average.)	0·870
Dissolved oxygen taken up in 24 hours (17)	0·630	2·191	1·446*
Suspended solids (7)	Mineral. 1 / Volatile. 0	Mineral. 0 / Volatile. 6	Mineral. 0·7 / Volatile. 3·3

* Corresponding oxygen absorbed from $KMnO_4$, 4 hours = 0·981.
Number of samples analysed for the average =

REMARKS.—Results as usual; grains per gallon and N as NH_3.

A. H. Valentine, M.Sc. (Chemist).

OLDHAM—*continued.*

November, 1904.

SEWAGE—

Average daily flow	5,340,000 gallons	Total Rainfall	5·52 inches.
Total	160,200,000 „	Average	0·184 „
Maximum daily flow	19,037,000 „	Rainfall	1·60 „
Minimum daily flow	2,090,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (27 experiments)	0·96	4·20	2·75
Albuminoid nitrogen (27)	0·335	1·13	0·670
Nitric nitrogen	—	—	—
Chlorine (30)	3·10	14·70*	6·71
Oxygen absorbed from $KMnO_4$ in 4 hours (26)	1·91	7·72	3·73
Dissolved oxygen taken up in 24 hours (18)	1·169	14·588	6·36†
Suspended solids (9)	Mineral. 10 / Volatile. 7	Mineral. 11 / Volatile. 67	Mineral. 12·7 / Volatile. 24·4

* Due to salt used in melting snow in streets.

† Corresponding 4 hours oxygen absorption from $KMnO_4$ = 4·17.

Number of samples analysed for the average =

TANK LIQUOR—

Average rate of flow through the tank - - 5,340,000 gallons daily.
Amount of sludge dealt with during the month - about 409 tons (50 per cent. moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen 17 experiments)	0·72	4·40	2·78
Albuminoid nitrogen (17)	0·21	0·77	0·474
Nitric nitrogen	—	—	—
Chlorine	1·70	9·80	6·40
Oxygen dissolved from $KMnO_4$ in 4 hours (47)	0·50	4·60	2·61
Dissolved oxygen taken up in 24 hours (18)	0·658	10·262	4·87*
Suspended solids (9)	Mineral. 2 / Volatile. 7	Mineral. 13 / Volatile. 7	Mineral. 4·7 / Volatile. 7·6

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 2·79.

Number of samples analysed for the average =

FILTERS—

Amount of tank liquor treated on filters during the month - 92,495,000 gallons.
Average number of fillings per day - 1·59+
Rate of filtration in gallons per cube yard per 24 hours - 82·4–

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (46 experiments)	0·18	2·65	1·31
Albuminoid nitrogen (46)	0·05	0·36	0·207
Nitric nitrogen (86)	0·92	0·07	0·171
Chlorine (47)	2·40	9·10	6·04
Oxygen absorbed from KMnO in 4 hours (26)	0·11 (As daily average.)	1·312 (As daily average.)	0·650
Dissolved oxygen taken up in 24 hours	0·140	2·051	0·894*
Suspended solids (10)	Mineral. 0 / Volatile. 0	Mineral. 2 / Volatile. 4	Mineral. 1·3 / Volatile. 1·5

* Corresponding 4 hours O. absorption from $KMnO_4$ = 0·732.

Number of samples analysed for the average =

REMARKS.—A new filter comes into operation at the beginning of November On several days during the month the filters were only filled once (during day time) on account of thick fog.

Results as usual. Grains per gallon and N. as NH_3

A. H. Valentine, M.Sc. (Chemist).

December 7th, 1904.

OLDHAM—*continued.*

December, 1904.

SEWAGE—

Average daily flow	5,631,387 gallons	Rainfall	4·94 inches.
Total	174,573,000 „	Average	*0·159 „
Maximum daily flow	13,939,000 „	Rainfall	0·882 „
Minimum daily flow	2,633,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen (23 experiments)	1·40	3·90	2·63
Albuminoid nitrogen (23)	0·30	0·96	0·637
Nitric nitrogen	—	—	—
Chlorine (31)	3·40	7·90	5·81
Oxygen absorbed from $KMnO_4$ in 4 hours (27)	1·37	5·37	3·33
Dissolved oxygen taken up in 24 hours (17)	2·625	10·101	5·74*
Suspended solids (8)	Mineral. 6 / Volatile. 6	Mineral. 37 / Volatile. 23	Mineral. 12·1 / Volatile. 18·0

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 3·53.

Number of samples analysed for the average = .

TANK LIQUOR—

Average rate of flow through the tanks - - - 5,631,387 gallons per 24 hours.
Amount of sludge dealt with during month - - 458 tons (of about 50 % moisture).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen (24 experiments)	1·00	4·10	2·52
Albuminoid nitrogen (24)	0·195	0·67	0·450
Nitric nitrogen	—	—	—
Chlorine (49)	2·10	8·90	5·56
Oxygen absorbed from $KMnO_4$ in 4 hours (45)	0·61	4·35	2·27
Dissolved oxygen taken in 24 hours (17)	1·470	8·428	4·08*
Suspended solids (8)	Mineral. 1 / Volatile. 3	Mineral. 9 / Volatile. 7	Mineral. 4·6 / Volatile. 6·1

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 2·43.

Number of samples analysed for the average = .

FILTERS—

Amount of tank liquor treated on filters during the month - - 95,830,000 gallons.
Average number of fillings per day - - - - - - 1·58+.
Rate of filtration in gallons per cubic yard per 24 hours - - - 82·2.

Average Analysis of Final Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen (42 experiments)	0·13	2·45	1·175
Albuminoid nitrogen (42)	0·085	0·29	0·185
Nitric nitrogen (86)	0·84	0·07	0·143
Chlorine (47)	3·00	7·30	5·34
Oxygen absorbed from $KMnO_4$ in 4 hours (27)	0·03 (As daily average.)	1·294 (As daily average.)	0·519
Dissolved oxygen taken up in 24 hours (17)	0·364	1·834	0·733*
Suspended solids (5)	Mineral. 0·5 / Volatile. 0·5	Mineral. 1 / Volatile. 4	Mineral. 0·6 / Volatile. 1·2

* Corresponding 4 hours oxygen absorption from $KMnO_4$ = 0·614.

Number of samples analysed for the average = .

REMARKS.—Results in terms as usual. On four days during the month, owing to thick fog, many filters were filled once only instead of twice, thereby affecting "average number of fillings per day," etc.

January 11th, 1905. *A. H. Valentine, M.Sc.* (Chemist).

Mr. James B. Wilkinson, M.D. (Edin.), D.P.H., F.C.S., Medical Officer of Health for the Borough of Oldham, and in charge of the Oldham Sewage Works, called in; and Examined.

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22565. (*Chairman.*) You are Dr. James B. Wilkinson, Fellow of the Chemical Society, and in charge of the Oldham Corporation Sewage Works?—Yes.

22566. And you have come before us to-day to give evidence with regard to your experience of the treatment of sewage, with special reference to the Oldham Sewage Works?—Yes.

22567. What is the population draining to the Oldham works?—About 140,000.

22568. What is the system of drainage—that is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent?—The drainage system is a combined one, and all the storm water finds its way into the sewers, though it does not all reach the sewage works.

22569. Is there any infiltration of subsoil water into the sewers?—Very little of the ground or subsoil water finds its way into the sewers, as even the old sewers are very water-tight. The borough surveyor estimates only about 100,000 gallons per day.

22570. What is the water supply per head, and from what source does it come?—The water supply is obtained from moorland gathering grounds, situated among spurs of the Pennine range of hills in the West Riding of Yorkshire; the supply is about 23 gallons per head (inclusive both of domestic and trade supply).

22571. Is it hard or soft water?—Very soft water, 3-4 degrees

22572. What is the drainage area of the part of the town which is sewered?—Practically the whole of the inhabited portion of the town is sewered, and the drainage from an area of about 3,700 acres reaches the sewage works. The remaining portion of the town is grass land, very sparsely populated.

22573. What proportion of the population use pail closets or middens and what proportion use water closets?—The number of pail closets, etc., in the town is as follows:—Pail closets, 14,308; cesspools, 25; total, 14,333. Water closets, 2,828; waste water closets, 12,049; latrines, 1,448; total, 16,325. The number of population using pail closets is about 75,000. Those using water, waste water, etc., about 65,000. This is only an approximate figure.

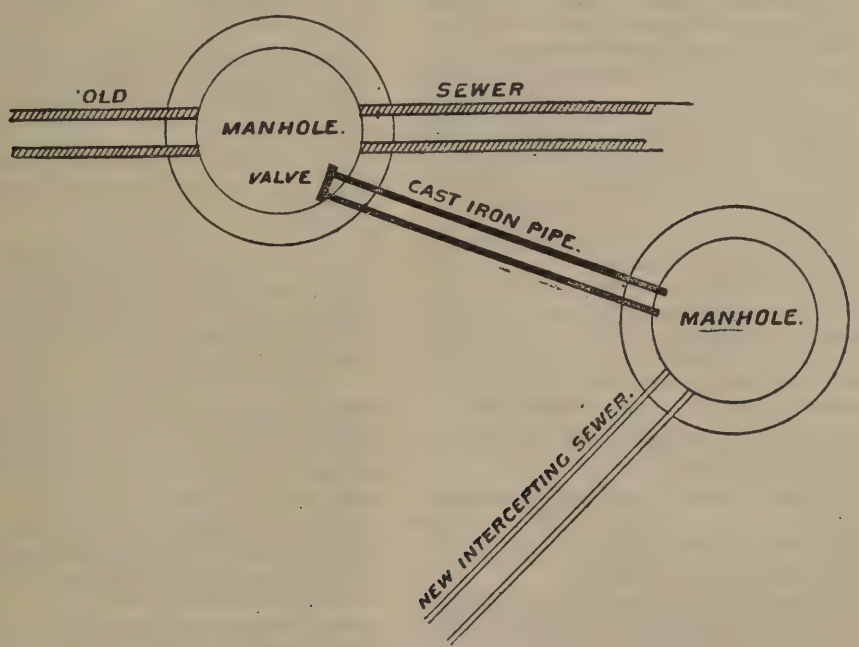
22574. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather (1) in winter and (2) in summer?—The amount of sewage reaching the works is registered and recorded by an automatic gauge which has been in use since the works commenced. The average amount of dry weather flow is about (1) 4,500,000 gallons in winter and (2) 2,700,000 gallons per day in summer.

22575. What is the maximum dry weather rate of flow, and at what hour does this occur?—The maximum is at the rate of about 6,700,000 gallons per day, and the greatest flow as a rule from 6 to 7 p.m.

22576. What is the minimum dry weather rate of flow, and at what hour does this occur?—The minimum is at the rate of about 750,000 gallons per diem, and occurs from 4 to 5 a.m.

22577. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—36,000,000 gallons per day. This flow continued for a considerable number of hours during the day—exactly how many the fluctuations of the gauge render it difficult to calculate—but on this day over 24,000,000 gallons reached the works.

22578. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation?—The Borough Surveyor replies to this question as follows:—There are overflows on the old sewers when connected to the main intercepting sewer. These connections calculated to discharge an ultimate flow based upon the following data:—60 persons per acre (statute), 35 gallons per head per day, plus ¼ in. of rainfall in 24 hours.



Type sketch showing system of intercepting old sewers.

22579. What is the largest number of gallons of sewage which have passed the last storm overflow and come to your works in 24 hours?—24,000,000 gallons.

22580. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—The average yearly rainfall in Oldham is 48-50 inches, and is equal to about 5,200,000,000 gallons.

22581. Can you give the Commission an approximate statement as to (a) the volume of sewage which comes to your works during the year; and (b) the volume which passes over your overflows?—In 1902 and 1903 the amount which reached the works was: 1902, 1,466,128,154 gallons (rainfall, 47·30 inches); 1903, 2,062,406,000 gallons (rainfall, 63·61 inches). The amount passing over the storm overflows on the sewers is not estimated.

22582. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—The amount of subsoil water gaining the sewers increases somewhat in wet weather and in the winter. The only approximate idea as to the amount is that which is given by the difference between the

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dry weather flow in winter and the dry weather flow in summer. The former averages about 4,500,000 gallons per day, and the latter about 2,700,000 gallons per day. This amount includes also drainage from springs, old land drains, and water from land not built upon, and is not true subsoil water.

22583. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of these effluents?—There are practically no true trade effluents in the town; there are small quantities of sewage from tripe works, slaughter-houses, and a small quantity of brewery refuse and from small dye works. The effluent from the mill reservoirs is the most notable pollution. The contents of these reservoirs when foul or putrid are often emptied into the sewers, and render the sewage very concentrated.

22584. Has your authority framed any rules as to the reception of trade effluents into sewers?—No.

22585. Do you find that the trade effluents interfere with the process of purification?—Except for the effluent from the mill reservoirs rendering the sewage very concentrated and foul the amount of trade effluent is not in sufficient quantity to affect the purification of the sewage. One notable exception may be mentioned, when on one occasion a large quantity of beer was turned into the sewers. The effect on the filters was very marked, throwing them out of working order for 3 or 4 days.

22586. In dry weather what is the average amount of suspended matter in the sewage, and what are the highest and lowest figures in parts per 100,000?—Average, 47·9 grains per 100,000. Minimum, 10 grains per 100,000 (first fine day after heavy rains); maximum, 188·6 grains per 100,000 (evidently mill reservoirs being emptied).

22587. What is the physical character of these solids?—Fine ashes, flocculent material, cotton fibre, and organic material and fat.

22588. Can you give us average analyses of the sewage for the years 1903 and 1904, in summer and in winter?—The results are given in the tables which are handed in.

22589. Is it a "strong" sewage, and, if so, what characterises its strength?—The sewage would, I think, be best described as "a strong domestic sewage."

22590. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of the final effluent to a marked degree?—Yes; the variation in the strength of the sewage is considerable, both in the day of the week, and, as is usual, in the time of the day. On Monday and Tuesday the sewage is usually very strong, supposed to be due to these days being the general washing days in the borough. The variations affect the quality of the effluent to some effect.

22591. How do you think "strength" of sewage as affecting purification is best expressed or measured?—Probably the number of grains of oxygen absorbed by the permanganate test is as good as any, except where there is an excess of acid or chemical ingredient.

22592. Have you any information as to the bacteriological condition of the sewage?—No.

22593. Are there any chemical poisons in the sewage?—No.

22594. Is the sewage always alkaline?—Generally almost neutral or very slightly alkaline.

22595. Do you find that the amounts of suspended solids are increased or diminished in times of storm, and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—At first the amount of suspended solids is increased very rapidly after a storm, the increase being more marked where there is a sudden rush of water, but after a short time, depending on the amount of flow, the amount rapidly decreases.

22596. How many years ago were your sewers laid, and do you know whether they have sunk much in places, so as to allow solids to accumulate?—The older sewers were laid 30, 40, or more years ago; the newer main intercepting sewer, which practically forms a belt round the town, was laid about eight to ten years ago. There is very little sinking, and the older sewers are mostly laid at very steep gradients, which prevents the accumulation of solids. The newer intercepting sewer has a much slighter fall, and when there is a small flow there is some deposit in this sewer.

22597. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times?—This depends considerably on the condition of the sewer and the fall or the rapidity with which the sewer reaches the works. In our works, at the commencement of a storm, more than three times the normal amount would be dealt with advantageously by the ordinary tanks and filters, while later on considerably less than three times the normal flow is often quite fit to be turned direct into the stream. With sufficient tank room the first flow can be dealt with on the ordinary plant. The sedimentation of our storm water after the first rush in a quiescent tank gives a very clear effluent. This treatment would not be sufficient for the first rush of storm water, and even when settled in a quiescent tank the sludge deposited by the afterflow very soon putrefies.

22598. What shape and size are your storm overflows?—There are no storm overflows at the works; those on the sewers have been previously described.

22599. Would it be possible to have a standard form of overflow; and how would you fix the point at which overflows should be allowed to come into operation?—Possibly in some towns where there is a very regular flow, and probably with a satisfactory result. In large works, with an experienced man in charge, a much better result would be obtained by observing the condition of the sewage.

22600. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—Yes, certainly.

22601. Should storm overflows be fixed or movable?—Movable, in large works, most certainly.

22602. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass?—Yes, upon the relative size of the volume of the stream to that of the amount of sewage discharged into it, rather than the actual size of the stream; and upon the rapidity of the flow in the stream also.

22603. Have you had any experience of the separate system of drainage?—No, beyond the knowledge that the first washings from the streets is an exceedingly polluted liquid.

22604. Is your sewage settled, and, if so, how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—The Oldham sewage passes through sedimentation tanks, of which there are 12 parallel ones. The flow through them is continuous, The tanks are 128 ft. long, 36 ft. wide, and 6 ft. 2 in. deep, and they each have a capacity of 176,000 gallons. There are usually from six to eight of them in use, and the time the sewage takes to pass through varies from 4 to 10 hours or more, the variation depending on the flow of sewage, the amount of sludge in the tanks, and the number of tanks in use. An analysis is given in the tables which are handed in.

22605. Have you data to show what proportion of the suspended matter in your sewage is settled in ½-hour, 1, 2, 3, 4, 5, 6, 12, and 24 hours, if the sewage is given quiescent settlement?—No.

22606. What time would be necessary for you to gain a good tank liquor containing, say, no more than 6 or 8 parts of suspended solids per 100,000 from your sewage (without the addition of chemicals), (1) by quiescent settlement, (2) by continuous flow settlement?—Probably 6 to 8 hours in continuous flow settlement.

22607. Do you prefer to use settlement tanks in series or in parallel?—Our tanks are in parallel, but personally I should prefer tanks to be divided by a cross wall into two. Where the sewage is not desired to become septic probably there is not a great deal of difference.

22608. In the case of continuous flow tanks do you think there is any advantage in the employment of baffling boards or walls?—I have had no experience.

22609. How is the sludging of tanks done at your works, and what is the character of the sludge? Have

you means of storing sludge, or do you have to get rid of it as soon as it is removed from your tanks?—The flow into the tank is shut off. The supernatant liquid is drawn off by a floating arm on to special filter beds. The sludge then either flows or is pushed into the sludge channel where it is mixed with slaked lime. The mixed sludge is then lifted to a ram from which it is forced by compressed air into the presses. There is no nuisance. There are two large tanks into which the sludge, when too thin to be pressed, can be pumped and then allowed to settle. The pressed sludge is either carried away by farmers or dumped into a large valley in the works.

22610. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—Road detritus, ashes, etc., are best removed by preliminary detritus tanks, they interfere with the sludge pressing.

22611. What is the manurial value of the sludge, and will farmers take it?—No thorough analyses have been made, but from observations and experience it has an excellent effect on grass lands. It contains a considerable quantity of nitrates, but is very deficient in phosphates; probably the lime in the pressed sludge is also beneficial. Most of the farmers in the neighbourhood of the works use it for their grass land. There is no cultivated land in the district.

22612. Are there any chemical poisons in it?—No.

22612*. Do you find any nuisance from the treatment of sewage in settlement tanks? Have any complaints been made?—No.

22613. Have you had experience of the chemical precipitation of sewage?—Chemical precipitation was the method in use at these works for about three years.

22614. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—The general observation was that simple sedimented sewage gave a better result from the filter beds than that precipitated by chemicals, and that the cost of chemicals was, as a rule, unnecessary: on the other hand, where the tank accommodation is small, or when, as occasionally at our works during hot, dry weather, the sewage is very concentrated and rapidly becomes septic, it is necessary to use chemicals to induce a more rapid precipitation. A septic effluent, if containing the same amount of solids gives a better result than either.

22615. Have you tried various chemicals?—Only lime and copperas.

22616. What is the most effective way of adding chemicals?—At the Oldham works the lime was added as lime-water and the copperas in solution. The amount was varied automatically, according to the amount of sewage flowing down, by an apparatus devised by the late Mr. Henry Law, and consisting of floats acting on valves.

22617. What length of time did the sewage remain in the tanks?—There was a continuous flow through the tanks, taking from 6 to 12 hours to pass through.

22618. Did you find it necessary to add further chemicals to the sludge before it could be dealt with? If so, for what reasons, and what chemicals did you use, and how were they added?—It is necessary to add lime to the sludge to kill the grease before it will press readily. The chemically precipitated sludge appeared to press better than the sedimented, probably owing to the lime being more intimately mixed with the sludge. Slaked lime is added and mixed by manual labour.

22619. What was the manurial value of the sludge obtained by the chemical precipitation of the sewage, and would farmers take it?—I would refer you to my reply to a similar question as regards sludge from sedimentation tanks. There is no difference.

22620. Did it contain any chemical poisons?—No.

22621. Did you find any nuisance from the treatment of sewage in chemical precipitation tanks? Were any complaints made?—No.

22622. As regards septic tanks, how should they be shaped?—Rectangular; and probably advantageous to have the floor shaped so that the part of the sludge can be drawn off from time to time without emptying the tank.

22623. Should they be divided into sections, and should they be used in series or in parallel?—I should prefer them in either series or with walls dividing them into sections, as we found that the sludge was broken up by the process of fermentation and lumps carried to the surface, and if this happened near the outlet end, a considerable amount of solid matter was carried over. If the heavier sludge were retained in the first tank or section, less solids would be carried over.

22624. Is a scum necessary or desirable?—I have no evidence to show; but the result of some experiments I made was that liquefaction or re-solution of the organic material took place much more rapidly in the dark, and by forming a cover to the tank the scum may be of assistance, and also allow greater bacterial growth.

22625. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—If the scum is of any value, then covering in the tank is also valuable, as the scum becomes broken up and entirely cleared off the surface by rain, and more especially wind; otherwise we found no advantage.

22626. What do you consider the best arrangement for the "feed" and "draw-off"?—I have very little experience, except that the draw-off must be below the surface, and, if it is desired to have an air-tight tank, the feed also.

22627. At what rate is sewage, as a matter of custom, passed through your septic tanks?—Not possible to say through the septic tank.

22628. What is the most advantageous rate of flow through septic tanks; is it possible to "over-septicise" a sewage; and what is the amount of digestion?—I cannot give you any reliable information on these points.

22629. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?—I am in favour of drawing off the sludge while working, thus conducing to a greater capacity in the tanks and more regularity in working.

22630. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—We have found great difficulty in pressing the sludge from septic tanks, and it has been allowed to solidify in storage tanks, and, by drawing off the surface water, allowed to dry naturally.

22631. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank?—Yes, considerably.

22632. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—The first portion of the storm water must be treated, and if not in too great an amount and too long continued, appears to cause no great harm to the septic tanks.

22633. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank, and, if so, can you give us figures (in parts per 100,000) showing what the increase is?—I have no information on this point.

22634. May you admit storm sewage to your septic tank to an extent which raises the ordinary level of the liquid, without serious detriment to the functions of the tank?—I have had no experience of this.

22635. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—No.

22636. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor? Kindly state what observations you have made on this point along with what you consider the reasons for advantage or disadvantage of the one or other process?—A better effluent is obtained from the filters from a septic tank effluent, and this effluent seldom undergoes putrefaction when incubated. A filter effluent from a septic tank of the same standard as that from a sedimentation tank is much less likely to again undergo putrefaction.

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22637. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—I have had no experience.

22638. Have you any data on the relative value of plain septic tanks, and septic tanks filled with rough stones or flints?—No.

22639. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—No.

22640. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered?—Yes.

22641. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement. I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis?—I am unable to give any comparison as to the cost of the various methods. The procedure which I believe will be most effective at the Oldham works, and which I expect will shortly be tried, is that of combined sedimentation and septic tanks. I have advised this for the following reasons:—(1) With sedimentation tanks we do not get such a good effluent from the filter beds as with a moderately weak septic tank effluent. (2) If the whole of the sewage is treated in septic tanks, when the tank becomes properly septic, giving a good result, the solid sludge begins to break up, and the suspended solids become considerably increased, and when these tanks are emptied, the sludge is pressed with difficulty, even when considerable quantities of lime are added. The method I have suggested is to run the sewage after it passes the detritus tanks into a sedimentation tank with a continuous and moderate flow, taking from two to four hours to pass through. In this tank all the heavier solid sludge will be deposited, and these tanks being emptied at frequent intervals, the sludge will be pressed while fresh. From this tank the partially settled sewage will flow into the two lateral tanks with a flow of from 4 to 10 hours, and these tanks will be maintained as open septic tanks. By this method, I anticipate, we shall obtain what is a most satisfactory tank effluent for filter beds, viz., a weak tank effluent; maintain the septic tanks at their greatest capacity, as there will be little sludge in the tanks, and they will only require cleansing at long intervals.

22642. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—Possibly a somewhat clearer effluent may be obtained when the walls and floor of the filter bed are constructed of impervious material, but all our filter beds are lined with timber, only the floor being the natural soil. No disadvantage has been found to result; of course, our works are far removed from any source of water supply, and the subsoil is more or less of a clay. With chalk or a sandy soil it might be absolutely necessary to make the beds watertight to prevent contamination of water supplies.

22643. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—A few years ago I carried out some experiments, the following being briefly the procedure and results:—Glass tubes were inserted in a filter bed in such a way that the sewage in the bed could be admitted to them and drawn off for testing at any period after filling the bed. The depths at which the sewage could be drawn were 6 in., 12 in., 18 in., and 24 in. The general results were that (1) the sewage in the upper layers of the bed were much more rapidly purified than in the deeper layers; (2) a rough idea was obtained that the sewage at 6 in. depth was purified to the same extent in one hour as the sewage at 18 in. in two hours and the sewage at 2 ft. in three hours' contact. From these and other observations, I came to the conclusion that beds above 3 ft. deep would not be so satisfactory or economical in the working.

22644. What do you consider the most convenient size for a contact bed?—This depends entirely upon the amount of sewage. The beds should be able to be filled in one or one and a half hours for economical working.

22645. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is, in your experience, the least disintegrable in a contact bed?—Our earlier beds were constructed of screened mill ashes. In the year 1900, I suggested that the clinker from the refuse destructors should be broken up, screened, and used for this purpose. Their use has proved satisfactory, and for the last three years practically all the clinker from the refuse destructors (except the fine material) has been used to construct our filter beds. It is a hard material, and appears to disintegrate very slowly. The mill ashes disintegrate much more rapidly and assist in the growth of weeds and diminish the capacity of the beds.

22646. What size should the filtering material be, and should it be graded?—All material passing a ¼in. mesh is removed. The beds are not graded.

22647. How should the bottom af the bed be constructed?—Ours have two rows of drain pipes in the bottom of the bed, and there is a gradual slope towards these.

22648. Do you think it generally advisable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—The Oldham sewage would very quickly block up the beds unless it was treated first in tanks.

22649. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working?—Filling, 1½ hours; standing full, 2 to 3 hours; and remaining empty, 2 to 6 hours.

22650. How should contact beds be filled and emptied?—The Oldham beds are filled either from wood or pipe channels on the surface of the bed. These either cross the bed or radiate from one point. The beds are emptied slowly at first, and when about half empty the valves are open to the full bore.

22651. Have you had experience of automatic gear for filling and emptying contact beds?—No.

22652. What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed in 24 hours? If the amount varies with the quality of the tank liquor, please state by analytical figures what quality of tank liquor you are assuming in your answer, and how differences in the tank liquor affect the amount that can be properly treated?—With an average tank effluent of, say, 3-5 grains of oxygen in 100,000 in 4 hours' test, and a filter bed in which the working is well established, I do not consider that above 100 gallons per cubic yard can be economically treated, having regard to the life of the bed, though a much larger quantity than this can be efficiently treated; but the life of the bed will be, in my opinion, considerably lessened. I am referring to single contact beds.

22653. Can this quantity be increased by more frequent filling and emptying in times of storm, without impairing the efficiency of the beds or the quality of the effluents?—Yes; a flow of weak sewage through a filter bed occasionally has often very beneficial results. Even a continuous flow through the beds for some hours seems to act rather beneficially than otherwise if the sewage is sufficiently weak.

22654. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent? If so, please state in precise terms (*i.e.*, by analytical figures) of what tank liquors you are speaking, and what effluent you are regarding as satisfactory?—Yes; with, say, 3 hours' contact, and a tank effluent not exceeding 4-5 parts per 100,000 of oxygen in 4 hours' test. If a longer contact is given, a much worse sewage will give a satisfactory effluent.

22655. At what rate or rates do contact beds lose their water-holding capacity?—No definite figures can be given by me, but they rapidly lose their capacity to about 35 per cent. of the original, and if not overworked and with occasional rests, the capacity can be maintained at 30 to 35 per cent. for several years. Five years after use our beds showed little alteration from this.

22656. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed, or to the fineness or coarseness of the material of the bed, or on what does it depend?—The loss of capacity is in direct proportion (a) to the volume treated and to the amount of suspended solids contained in the liquid; (b) to the fineness of the material of the bed; (c) to the liability of the material of the bed to undergo disintegration. Clogging is also caused by insufficient drainage of the bed after contact.

22657. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard?—I have no experience as to this.

22658. What is the average analysis of your contact bed effluent?—Analyses are given in the tables which have been handed in.

22659. Do you find any chemical poisons in your final effluent?—No.

22660. What is the average amount of suspended matter in (a) the primary bed effluent, and (b) the secondary bed effluent? Does most of this suspended matter come out with the first flush or not?—Analyses are given in the tables.

22661. Is the first flush of effluent ever putrescible?—Yes, if taken by itself.

22662. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency, and, if so, do you think there are advantages in so working them?—Yes; and after being so used, and a rest, the results of future filling are better.

22663. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per 24 hours in ordinary times and in storm times?—Our contact beds cost from £1,000 to £2,000 per acre. All beds are used as single contact, though arranged so that if necessary in the future some of them can be used as second contact beds. The depth is an average of 3ft.

22664. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—No.

22665. Have you had any experience of continuous or percolating filters?—I have no practical experience. From the information given me on visiting places where percolating filters are in use, my impression is that the amount of sewage which can be efficiently passed through them is much about the same per cubic yard as in contact beds.

22666. (*Colonel Harding.*) How long have the tanks at Oldham been going?—(*Mr. Wilkinson.*) The contact beds were started in 1897.

22667. Then your experience at Oldham with the contact beds is an experience of eight years?—From 1897; October, 1897, I think.

22668. Perhaps you can answer this point, Mr. Wilkinson; have you found that you have reached the point with your contact beds when it is necessary either to renew the material or to wash it?—Yes, we have at present in two or three of the oldest beds.

22669. Can you tell us how long under the conditions at Oldham a contact bed can go on without having either its material renewed or washed?—I think that requires some qualification; it depends to a great extent—at least my experience shows—upon the amount of sewage that you treat on it.

22670. Clearly, but with the conditions you have at Oldham how long were you able to run your contact beds before you reached that?—In the first four years we treated practically as much as was treated at first; during the last two years we have been considerably pressed to treat the whole of our sewage without having sufficient beds, and in consequence we have been overworking them, and that, I think, is the reason that has shortened their life very considerably.

22671. Are you able to give an answer to my question, in the conditions of over working in the later period how long have they in fact lasted before they reached the time when it was necessary?—That is a question I could not answer, because for the first four years—at the end of four years—they were practically as good as they were at the first year, and if we had gone on using them at the same rate they would probably have kept in the same condition.

22672. As a matter of fact, when did any of them reach the condition when it was necessary to either renew or wash?—Well, we are using them all at the present time.

22673. They have not reached it at all?—We can use them, but the capacity of course has been considerably reduced.

22674. How far may one use a contact bed; down to what point of reduced capacity is it practical to use a contact bed before one must wash it out?—As long as it will take the sewage.

22675. Well, not as long as it takes any sewage, for it reaches a time that the amount of the sewage it takes is too small. This is rather a practical question, not a theoretical one. I am putting it to you. It may be that it would take sewage for many years in minute quantities, but the point is a practical one; down to what amount capacity reduction can you work a contact bed?—I should say it would not be economical treatment when it gets down to 15 per cent. *Mr. James B. Wilkinson, M.D. (Edin.), D.P.H., F.C.S.* 11 May 1905.

22676. 15 per cent. of what?—Of the total capacity.

22677. About 30 per cent. of the original water capacity?—Yes.

22678. Can you tell us from your experience at Oldham, working under conditions which in your opinion would not overwork the beds, how many years would contact beds be able to last before they reached that position?—I am of opinion that they may last a very considerable number of years.

22679. What do you call a very considerable number of years—seven, ten, fifteen?—I cannot tell you; for this reason, that at the end of four years they were practically of the same capacity as they were the first year.

22680. Then we are to take it from you that the contact beds you have had working for eight years at Oldham are still working and capable of working for some time longer?—Oh, certainly; only the older ones do not take so much sewage.

22681. Your experience does not permit you to express an opinion how long a contact bed may be worked in practice before reaching the time when it is necessary to wash out the material?—When it becomes economical to renew it?

22682. Yes; you cannot tell us?—I could not, because our beds were working at the end of four years as well as they were the first year.

22683. You cannot give us that information; you say you cannot tell us when it would be reached, but when it is reached is it practicable to wash the material?—That depends on the material. In some of the early beds the material has fallen very considerably, and if they are washed there will be very little material fit to be put into the beds again. Our newer beds are made of a very much harder material, which does not fall away readily when it is washed, and a very large proportion of it will be able to be put into its place again.

22684. If suitable material is used, do you consider it generally practicable to wash the material of the contact bed?—Quite so.

22685. You have not been able probably to form any estimate as to what the cost would be?—No.

22686. I do not know whether you have heard it stated that the price elsewhere has been something like 1s. 6d. to 2s. a cube yard?—I have heard it stated at from 1s. up to 1s. 6d. per cube yard.

22687. You are unable to say probably whether that is a likely figure or not?—I have not any experience of the cost; I could not say.

22688. But I gather from what you have told us that you largely appreciate the importance of the question of disintegration in connection with the reduction of capacity in the contact beds?—Oh, yes; that is a great feature.

22689. And the great aim will be to get material which is not friable or is only friable to a small a degree as possible?—That is so.

22690. Can you throw any light on the best kind of material, having that point in view?—The material we use at present, as far as I can see, is thoroughly satisfactory—that is crushed clinker from the refuse destructors, which is almost a slag.

22691. Is it thoroughly well vitrified? If you have destructor clinker in some cases insufficiently vitrified, it is extremely friable?—Yes; if insufficiently burned, but ours passes through a crusher, and then it is screened so most of the material of a friable nature is broken up, and goes away in dust.

22692. It has been suggested to us that it would be worth while to thoroughly wash such material before putting it into a new bed for the purpose of eliminating the small friable portions; do you think that would be practicable?—I do not think that would be any benefit at all, so far as our material is concerned.

Mr. James B. Wilkinson, M.D. (Edin.), D.P.H., F.C.S.,

11 May 1905.

22693. You do not think so in this instance?—The material, if it is properly screened, is perfectly clean.

22694. You have had at Oldham, I understand, no experience of your own on percolation filters?—No, I have not.

22695. (*Major-General Carey.*) These effluents from your contact beds discharge directly into the river?—Yes.

22696. Have they always been satisfactory?—I think the average has always been satisfactory.

22697. Does it comply with the standard of the Mersey and Irwell Board?—Yes.

22698. Always?—Yes, I think the effluent always, except perhaps I might say a very occasional exception during the very hot summer, when the sewage becomes exceedingly concentrated; that is very occasional.

22699. (*Chairman.*) Mr. Wilkinson, on Question 22624 you say that liquefaction took place much more rapidly in the dark. Now may I ask whether your experiments were extensive?—They were not very extensive.

22700. And on Question 22636, there again you say that a better effluent is obtained from filters from a septic tank effluent; were your observations numerous?—They are the results of the analyses by Mr. Valentine, the analyst, and by Mr. Wylie, who preceded him.

22701. There have been a great number of analyses?—Oh, a considerable number, extending practically over four or five years or more.

22702. (*Mr. Stafford*). On Question 22601.—Should storm overflows be fixed or movable? You say movable, in large works, most certainly. Why are you of opinion that they ought to be movable?—For the reasons given in one of the preceding questions. I think that we find that if we fix the storm overflow, drawing the water off at certain dilutions, the earlier flow will be in a seriously polluted condition, whereas the later flow at a much less dilution of the ordinary flow would be a very much weaker sewage than even you are required to send into the rivers.

22703. The reason I ask is because yesterday we got quite a different answer from some person, who was quite as positive that they ought to be fixed?—Well, that is my opinion.

22704. (*Major-General Carey.*) The regulations as to the overflow are, in your opinion, to be left to the local authority, to the surveyor?—I should think where you have experienced men in charge of the works he is a much better judge when he should send his sewage into the stream than any fixed overflow possibly could be, because it is simply automatic; it sends it in when there is a certain number of dilutions.

22705. No doubt, but it places a great responsibility upon him?—Undoubtedly.

22706. (*Mr. Stafford.*) Question 22166. Is the first flush of effluent ever putrescible? You say, Yes. What do you intend to do with it; it is putrescible liquor; are you going to discharge it into the river?—I take it that is only the first flush from the drains in the filter beds, because, mixed with the rest of the effluent from the bed itself, it does not become putrescible; it dilutes it sufficiently.

22707. Yes, but what becomes of it; do you discharge it into the river in this putrescent condition?—It mixes with the effluent from the other beds; it is simply the first water that comes from the actual drains that are in the bed.

22708. (*Colonel Harding.*) Do you think its putrescibility would not appear in the mixed effluent which is composed largely of first and last flows from various beds?—No, that is my reason.

SEVENTY-FIFTH DAY.

Friday, 12th May, 1905.

PRESENT:

The Right Hon. the Earl of Iddesleigh (*Chairman*) presiding.
Major-General Constantine Phipps Carey, C.B., R.E.
Colonel T. W. Harding, J.P.
Sir William Ramsay, K.C.B., F.R.S.
Mr. W. H. Power, C.B., F.R.S.
Mr. T. J. Stafford, F.R.C.S.I.

Mr. F. J. Willis (*Secretary*).

ALSO PRESENT:

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. Gilbert J. Fowler, D.Sc., F.I.C., Consulting Chemist to the Manchester Corporation Rivers Committee, Senior Chemical Assistant in the Public Health Laboratories, University of Manchester, called in; and Examined.

Mr. Gilbert J. Fowler, D.Sc., F.I.C.

12 May, 1905.

22709. (*Chairman.*) You have kindly come before us to-day, Mr. Fowler, to give further evidence with regard to your experience of the treatment of sewage, with particular reference to your work at the Manchester Corporation Sewage Works.

22710. What is the general treatment of sewage at Manchester?—Principally septic tanks followed by single contact.

22711. What is the population draining to the Manchester works?—The population draining to the sewage works at Davyhulme is 575,000. This is inclusive of portions outside the city area which drain into the city sewers by agreement, but exclusive of the districts recently added to the city, viz., Withington and Moss Side, which have sewage works of their own.

22712. What is the system of drainage—that is to say, is the storm water either wholly or partially drained into a separate system, and, if only partially, to what extent?—The area is almost entirely drained upon the "combined system," almost all the storm water is admitted, the excess over a defined quantity being passed off by storm overflows. Certain small areas and separate buildings, where circumstances permit, are drained on the separate system, but their total area is inconsiderable.

22713. Is there any infiltration of subsoil water into the sewers?—Yes; Mr. Baldwin Latham has estimated it at 6,000,000 gallons per day.

22714. What is the water supply per head, and from what source does it come?—The water supply of the city may be taken at an average of 29 gallons per head per day, viz., 16 gallons per head for domestic and 13 gallons for trade purposes. It is derived partly from reservoirs in the Longdendale Valley between Sheffield and Manchester, and partly from Thirlmere in the Lake district.

22715. Is it hard or soft water?—Manchester water is a soft water.

Longdendale Water.	Temporary hardness	·14	Parts $CaCO_3$ per 100,000 (Roscoe and Schorlemmer)
	Permanent „	3·43	
	Total	3·57	

22716. What is the drainage area of the part of the City which is sewered?—The drainage area contributing to the Davyhulme works may be taken as 11,800

acres. This includes portions of the out-districts admitted to the sewerage system under agreement, but does not include certain unbuilt areas.

22717. What proportion of the population use pail closets or middens, and what proportion use water closets?—About 62½ per cent. of the city population use pail closets and middens, and 37½ per cent. use water closets. This will apply to 560,000 of the population draining to the works; for the remainder figures are not available.

22718. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather in winter and in summer?—Yes; the results are given in the report of Rivers Department for year ending March 30th, 1904. The average flow per 24 hours in winter dry weather (October to March, inclusive) is found to be 26,481,000 gallons, and in summer dry weather (April to September, inclusive) 25,311,000 gallons.

22719. What is the maximum dry weather rate of flow, and at what hour does this occur?—The maximum dry weather rate of flow taken over a period is 37,236,000 gallons per 24 hours, occurring at 2 p.m.

22720. What is the minimum dry weather rate of flow?—The minimum dry weather rate of flow taken over a period is 18,644,000 gallons per 24 hours, occurring at 6 a.m.

22721. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—The maximum wet weather rate of flow observed was from 9 p.m. to 11 p.m. on August 6th, 1900, when it reached 222,625,000 gallons per 24 hours.

22722. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation?—There are in all 215 storm overflows on the sewerage system. They were designed to come into operation at a dilution of five to one.

22723. What is the largest number of gallons of sewage which have passed the last storm overflow and come to the works in 24 hours?—The greatest daily flow recorded was on Tuesday, August 7th, 1900, when 163,624,000 gallons passed down to the outfall works.

22724. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—The average yearly rainfall for three years amounts to 31·5 in. on the sewered area of Manchester, *i.e.*, on 11,800 acres. This represents 8,408,597,400 gallons per annum.

22725. Can you give the Commission an approximate statement as to the volume of sewage which comes to the works during the year, and the volume which passes over the overflows?—The volume which comes to the works during the year is from 12,000 to 13,000 million gallons. The volume which passes over the overflows cannot be accurately stated.

22726. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—Probably the amount of subsoil water is greater by one to two million gallons in winter than in summer time. The amount continues in excess of the normal for some time after a period of wet weather and vice versâ.

22727. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of these effluents? If you have analytical figures, please give them?—The following is a careful estimate of the character and quantity of the chief trade effluents in Manchester:—

	Gallons per day.
Brewers, Bottlers, Mineral Water Manufacturers, &c.	750,000
Dyers, Bleachers, &c.	550,000
Tanners, Leather Dressers, &c.	20,000
Oil and Grease Refiners, Candle Makers, Soap, Size, &c., Works	80,000
India-rubber Works	20,000
Galvanizers and Brass Finishers, including cooling water from wire rollers	550,000
Chemical Manufacturers, including Sulphate of Ammonia Works, Tar Distillers, Aniline Works, Alkali, &c.	1,150,000
Slaughter Houses (including Public Abattoirs), Tripe Dressers	15,000
Railway Companies, Carriage Washings, Sponge Cloth Washings, Engine Cleaning, &c.	150,000
Colliery Water	50,000
Trafford Park Engineering Works, principally cooling water	500,000
	Say - 3¾ million.

This may be taken at 14 per cent. of the daily dry weather flow. A large proportion of this volume is made up of comparatively uncontaminated liquids, such as cooling water and washing-off water. In our sewers, and not included in the above list, are large volumes of hydraulic engine water, water run off from the public swimming baths, condenser water, etc. I hand in analyses of typical samples of various trade effluents.

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TYPICAL SAMPLES OF VARIOUS TRADE EFFLUENTS

Effluent.	4 Hours' Oxygen Test.	3 Minutes' Oxygen Test.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Acidity (in terms of CaO).	Suspended Matter.	Chlorine.	Iron in Solution.
Colour Works - - -	95·43	49·14	1·06	1·65	56·0	No returns included, as results vary greatly and in most cases it is not difficult to remove most of the suspended matter before the effluent enters the sewers.	470·0	—
Galvanising Work - -	—	—	—	—	1,657		—	17,857
Rubber Works - -	228·57	—	—	—	(Strongly Alkaline).		—	—
Ammonia Recovery	708·57	411·43	8·23	12·76	—		—	—
Benzole Plant - -	334·29	114·29	2·70	·35	—		—	—
Print Works - - -	75·00	34·00	1·23	2·14	—		—	—
Indigo Dyers - - -	5·00	2·60	—	—	—		—	—
Abattoirs - - - -	47·86	18·57	41·16	8·23	—		213	—
Dyers and Bleachers -	255·71	75·71	tr.	1·31	—		—	—
Bone Washing -	60·30	14·43	2·41	15·64	—		—	—
Bleachers - - -	7·00	—	·82	·99	—		—	—

22728. Has the Corporation framed any rules for the reception of trade effluents into sewers?—Yes, I hand in a copy of the rules.

CITY OF MANCHESTER.

TRADE REFUSE.

Regulations for admission of Trade Refuse into Sewers.

1.—All liquid trade refuse from the manufactory shall be passed into and through suitable settling tanks to be approved by the Corporation, the same to be constructed and at all times maintained by and at the cost of the owner to the satisfaction of the Corporation.

2.—By means of the settling tanks and by such other means as shall be from time to time approved by the Corporation the resultant effluent shall be made:—

(*a*) Free from solids in suspension beyond 15 grains to the gallon;

(*b*) Free from any substance, matter, or thing which shall or may (either alone or in combination with other matter or liquid, or with the ordinary sewage);

(i) Be injurious to the structure or materials of the sewers or works of the Corporation;

(ii) Be injurious to the sewers or the sewage therein;

(iii) Cause or create a nuisance either within or without the sewers; and

(iv.) Be dangerous or injurious to health either within or without the sewers.

(*c*) Free from any substance, matter, or thing the discharge of which into the sewers may contravene any public or local Act of Parliament or Rule of Law.

3.—The owner shall remove as frequently as may be necessary from the settling tanks all solid refuse and solid matter which may be from time to time deposited therein.

4.—Only the effluent from the settling tanks which complies with Regulation 2 shall be discharged into the sewers.

5.—The maximum aggregate daily quantity of effluent which may pass from the manufactory into the sewer shall be agreed between the owner and the Corporation before any connection with the sewer is made or any works for that purpose are commenced. The size and capacity of the drain for conveying the effluent from the manufactory to the sewer shall be determined by the City Surveyor, and shall be such as having regard as well to the agreed maximum aggregate daily quantity of effluent as to the intended inclination of the drain will be necessary to secure that only such agreed quantity shall and may be conveyed into the sewer at a uniform and regular rate of flow throughout the 24 hours of every day.

6.—The owner shall provide and efficiently maintain a reservoir or receptacle at the manufactory sufficient to hold at least one-half the agreed maximum aggregate daily quantity of effluent, and shall cause the effluent to pass into such reservoir or receptacle, and be thence conveyed by the drain into the sewer.

7.—There shall be constructed and maintained by and at the cost of the owner at or near the outlet of the drain into the sewer an examination shaft and apparatus so designed as to enable the Corporation or their officers to obtain at pleasure from time to time samples of the effluent discharged into the sewer.

8.—The works shall be constructed and carried out to the satisfaction in all respects of the City Surveyor, and shall be at all times subject to these regulations and the Acts of Parliament (public or local), bye-laws, and regulations for the time being in force in the city of Manchester in relation to the subject matter of these regulations. In particular in the works of excavating for and making and maintaining the drain or anything therein or connected therewith the owner will adopt such measures and generally carry out the works in such manner as shall be suggested or required by the City Surveyor for ensuring the satisfactory execution of the work, for effectually protecting the sewers, drains, gas and water pipes, wires, tramlines, and apparatus for ensuring perfect stability for the surface of the street and for preventing the complete stoppage of the traffic thereon, provided that the fact of the City Surveyor giving or failing to give any instructions or directions respecting the works hall not relieve or exonerate the owner from any obligations or liability imposed upon him by these regulations or at law.

9.—Any work of removing the pavement and flagging of the street and of restoring and making good the same shall be done by the Corporation at the expense of the owner, and the owner shall pay any such expense to the Corporation on demand.

10.—The owner shall permit the City Surveyor or any other duly authorised officer of the Corporation to enter the manufactory from time to time and to inspect the condition thereof.

11.—If at any time the works provided for by these regulations or any of them or anything therein respectively shall in the opinion of the Corporation or the City Surveyor be in a dilapidated, unsafe, inefficient, or unsatisfactory condition, or if the same shall not be kept and maintained in proper working order, or shall not be duly and properly fulfilling these regulations in all respects, or if proper arrangements for removing the solids from the trade refuse are not in regular and constant operation, it shall be lawful for, but not

obligatory on the Corporation, in addition and without prejudice to their other remedies by statute or contract, at the risk and cost of the owner (after first giving to the owner one week's notice in this behalf), either to repair, reinstate, or complete the same, or to remove and disconnect the drain from the sewer as the Corporation in their absolute discretion may think fit, and to enter upon the property of the owner for the purpose of executing the necessary works in that behalf. The owner shall pay to the Corporation on demand the cost to be incurred by the Corporation in any such work of repair, reinstatement, completion, or disconnection, such cost to be from time to time ascertained and certified by the City Surveyor, whose decision shall be final and binding on all parties.

12.—Any costs and expenses which may be incurred by the Corporation, and which under these regulations shall be repayable to them by the owner, shall include five pounds per centum for superintendence, and shall carry interest at four pounds per centum per annum from and after the expiration of one calendar month after service upon the owner of a demand for payment of such costs and expenses.

13.—The arrangements contemplated by these regulations do not extend to the reception into the sewers of surface and storm water or of water which has been taken or diverted from a river, stream, or canal.

14.—The owner shall enter into an agreement, to be prepared by the Town Clerk, for securing the due observance of these regulations.

15.—In these regulations the following words have the meanings here assigned to them:—

"Owner" means and includes the owner and occupier for the time being of the manufactory.

"Manufactory" includes any works, manufactory, or premises in the City of Manchester in which liquid trade refuse is produced.

"City Surveyor" means the City Surveyor for the time being of the City of Manchester.

and words in the singular number include the plural and words in the masculine gender include the feminine.

TO THE CORPORATION OF THE CITY OF MANCHESTER.

I apply for your permission to make a connection from my works, situate , with the sewer in Street, in the city of Manchester, for the purpose of carrying the liquids from such works into such sewer.

The trade or process carried on at such work is that of a .

The maximum daily volume of liquids issuing from such works is about gallons.

In the event of my application being complied with, I undertake that the foregoing regulations shall at all times be duly observed by the owner and occupier for the time being of the said works.

The owner and occupier of the works are prepared to enter into an agreement for that purpose, to be prepared by the Town Clerk of Manchester.

The names and addresses of such owner or occupier are:—

Owner

Occupier

Signature

Address

Date

EXTRACTS FROM ACTS OF PARLIAMENT.

The Public Health Act, 1875.

21.—The owner or occupier of any premises within the district of a local authority shall be entitled to cause his drains to empty into the sewers of that authority on condition of his giving such notice as may be required by that authority of his intention so to do, and of complying with the regulations of that authority in respect of the mode in which the communications between such drains and sewers are to be made, and subject to the control of any person who may be appointed by that authority to superintend the making of such communications.

Any person causing a drain to empty into a sewer of a local authority without complying with the provisions of this section shall be liable to a penalty not exceeding twenty pounds, and the local authority may close any communication between a drain and sewer made in contravention of this section, and may recover in a summary manner from the person so offending any expenses incurred by them under this section (*a*).

The Rivers Pollution Prevention Act, 1876.

Sanitary authority to afford facilities for factories draining into sewers.

7.—Every sanitary or other local authority having sewers under their control shall give facilities for enabling manufacturers within their district to carry the liquids proceeding from their factories or manufacturing processes into such sewers:

Provided that this section shall not extend to compel any sanitary or other local authority to admit into their sewers any liquid which would prejudicially affect such sewers or the disposal by sale, application to land, or otherwise of the sewage matter conveyed along such sewers, or which would from its temperature or otherwise be injurious in a sanitary point of view:

Provided also that no sanitary authority shall be required to give such facilities as aforesaid where the sewers of such authority are only sufficient for the requirements of their district, nor where such facilities would interfere with any order of any court of competent jurisdiction respecting the sewage of such authority.

The Public Health Acts Amendment Act, 1890.

Injurious matters not to pass into sewers.

16.—(1) It shall not be lawful for any person to throw, or suffer to be thrown, or to pass into any sewer of a local authority or any drain communicating therewith, any matter or substance by which the free flow of the sewage or surface or storm water may be interfered with, or by which any such sewer or drain may be injured.

(2) Every person offending against this enactment shall be liable to a penalty not exceeding ten pounds, and to a daily penalty not exceeding twenty shillings.

Chemical refuse, steam, &c., not to be turned into sewers.

17.—(1) Every person who turns or permits to enter into any sewer of a local authority or any drain communicating therewith—

(*a*) Any chemical refuse, or

(*b*) Any waste steam, condensing water, heated water, or other liquid (such water or other liquid being of a higher temperature than one hundred and ten degrees of Fahrenheit),

which, either alone or in combination with the sewage, causes a nuisance or is dangerous or injurious to health, shall be liable to a penalty not exceeding ten pounds, and to a daily penalty not exceeding five pounds.

(2) The local authority, by any of their officers, either generally or specially authorised in that behalf in writing, may enter any premises for the purpose of examining whether the provisions of this section are being contravened, and if such entry be refused, any justice on complaint on oath by such officer, made after reasonable notice in writing of such intended complaint has been given to the person having custody of the premises, may by order under his hand require such person to admit the officer into the premises, and if it be found that any offence under this section has been or is being committed in respect of the premises, the order shall continue in force until the offence shall have ceased or the work necessary to prevent the recurrence thereof shall have been executed.

(3) A person shall not be liable to a penalty for an offence against this section until the local authority have given him notice of the provisions of this section, nor for an offence committed before the expiration of seven days from the service of such notice, provided that the local authority shall not be required to give the same person notice more than once.

(*a*) In the case of Peebles *v.* Oswaldtwistle Urban District Council, it was held that this clause would not authorise the passing into the sewers of liquids injurious to health [1897] 1 Q.B. 392.

Mr. Gilbert J. Fowler, D.Sc., F.I.C.

12 May 1905.

Provisions as to discharge of certain matters into sewers.

THE MANCHESTER CORPORATION (GENERAL POWERS) ACT, 1902.

21.—Where in the opinion of the Corporation the introduction of any solid matter, suspended matter, mud, chemical, or manufacturing or trade or other refuse (inclusive of vapours or gaseous matters), or any steam, condensing water, heated water, or other liquid (such water or other liquid being of a higher temperature than one hundred and ten degrees Fahrenheit) into a sewer, whether alone or in combination with other matter or liquid, and whether directly or through any drain or channel communicating therewith, either does or may cause a nuisance or involve danger to the health of persons entering the sewers or others, or is or may be injurious to the structure or materials of the sewers or works of the Corporation, the Corporation may by order absolutely prohibit from a date to be named in such order, not being earlier than fourteen days from the service of such order, any such matters or matter being caused or permitted to fall, flow, or enter or to be carried or washed into any sewer either directly or indirectly.

The Corporation shall cause a copy of any such order to be served upon any person who may in their opinion be acting in contravention thereof, and if any such person dispute the reasonableness of any such order as applicable to himself, or any works or premises under his control, such person may appeal to a stipendiary magistrate for the city, who shall appoint a referee to determine the reasonableness thereof, and any such referee may determine either that the said order ought not to be enforced as against the objector, or that it ought to be enforced either with or without modification or conditions, and may by his award determine that the person objecting should have reasonable time allowed to execute any works or any alterations on his premises which may be necessary in order to prevent the introduction of the matter into a sewer, and the costs of the award and determination and the costs of the parties thereto shall be in the discretion of the referee.

Any person who shall fail to comply with the terms of any such order after service thereof upon him, or in the event of an appeal to a referee with the determination of the referee, shall be liable to a penalty of not exceeding twenty pounds for every such default, and to a daily penalty not exceeding five pounds for every day on which the default continues after conviction thereof.

The Corporation shall in their discretion have the power of constructing within any manufacturing premises at the cost of the Corporation and without any liability on their part for compensation in respect thereof, an inspection chamber or chambers accessible to the Corporation officials at all times for the purpose of ascertaining the nature of the discharge from such premises into the sewers of the Corporation, and the Corporation or any of their officers specially authorised in that behalf in writing may at any time enter any such premises for the purpose of examining the nature of the said discharge and of taking samples thereof.

Any person who shall refuse to permit any such officer after production of his authority to enter into any premises, or shall obstruct any such officer in carrying out his duties under this section shall be liable to a penalty of not exceeding twenty pounds.

Nothing in this section shall be deemed to take away or affect any power of the Corporation to take proceedings under any other Act.

22729. Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume, or otherwise?—Yes, for the following reasons:—(a) The large quantity of iron pickling refuse greatly increases the volume of the deposit in the septic tank, and also the amount of insoluble matter going on to the beds. That is, however, rather a matter affecting the cost of purification than the actual chemical changes involved. It should, however, be mentioned that the chemical treatment to which the sewage was formerly subjected was rendered more difficult owing to sudden flushes of acid refuse. Constant vigilance is necessary on the part of the workmen in order to adjust the addition of the lime and copperas to the varying character of the sewage. In the presence of iron pickle the addition of copperas is, of course, discontinued, and the amount of lime added in some cases greatly increased. (b) Certain effluents, *e.g.*, naphtha-washings and carbolic acid, ammonia recovery liquor (containing sulphocyanates), and some dye-waste, greatly increase the oxygen-absorbing power of the sewage, and so increase the difficulty of bringing the effluent within the limits fixed by the Mersey and Irwell Joint Committee. It is probable that much of the nitrate which would otherwise appear in the effluent is used up in oxidising these various dissolved impurities. (c) Although the amount and character of the trade refuse has never been such as to effect complete sterilisation of the sewage, experience would show that the period of ripening of both septic tanks and bacteria beds is prolonged by the presence of trade waste. When the tanks and beds are fully ripe the purification is only effected under very exceptional circumstances. The following observations may be of interest:—On December 2nd, 1899, an accidental discharge of ammonia-recovery liquor into the sewer raised the oxygen absorption figure of the closed septic tank effluent to upwards of 24 grains per gallon; this was reduced by the filters dealing with this tank effluent to 2·56, and no subsequent ill-effects were noted. Half-acre beds which after several weeks' working failed to give a non-putrefactive effluent when only filled six times a week, two hours' contact being allowed, immediately gave non-putrefactive effluent when the period of contact was increased to 12 hours. With Manchester sewage, therefore, the best method of starting new beds appears to be to fill not more than once a day, giving at least 12 hours' contact, this period of contact being gradually reduced as the beds become more mature. With beds which have been in use for several years the total period of filling, standing full, and emptying need not exceed two hours. (d) An experiment was made as follows:—A sample of sewage was inoculated with septic sludge, and a series of bottles filled with the mixture. Into each bottle was placed a small portion of a particular trade effluent, and an arrangement was made for estimating the gas evolved in each case, one bottle of the series being left in its original state. In no case was the septic action actually stopped, but considerable variation was shown in the amounts evolved in each case. A similar result was obtained in a series of observations made, where varying amounts of salt were added to the mixture. The rate of evolution of gas, however, tended to become more equal in all cases after the lapse of some days. These experiments confirm, therefore, the conclusion of general experience that the effect of trade refuse is to increase the period required from the bacterial activity to attain its maximum, but is not sufficient, as a rule, to permanently effect the working of the various bacteria processes.

22730. In dry weather what is the average amount of suspended matter in the sewage, and what are the highest and lowest figures in parts per 100,000?—The figures for suspended solids are:—

——	Total.	Mineral.	Organic and Volatile.
Average - - -	35·0	16·5	18·5
Highest - - - -	40·6	18·9	21·7
Lowest - - - -	28·6	11·7	16·9

22731. What is the physical character of these solids?—The suspended matter referred to in the above figures does not include detritus and large floating matters which cannot be taken into the ordinary samples. An average sample of detritus was found to consist of a large proportion of sand, fine coal and cinder, a fair amount of coal in moderate-sized pieces, also gravel, clinker, small pieces of brick, wood, leaves, etc. Altogether there was about 35 per cent. of combustible matter in the dried sample. About 7 per cent. of the whole sample consisted of coal which could be picked out by hand. The garbage from the screens consists of paper, orange peel, rags, corks, fæces, etc. The actual suspended matter taken in the ordinary samples

and referred to in the figures given is in Manchester of a fairly granular character, and settles with comparative ease.

22732. Can you give us average analyses of the Manchester sewage for the years 1903 and 1904, in summer and in winter?—Yes; the analyses are:— *Mr. Gilbert J. Fowler, D.Sc., F.I.C.*

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Date.	4 Hours' Oxygen Test.	3 Minutes' Oxygen Test.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Chlorine.
January-March, October-December 1903	10·81	5·54	2·13	·49	18·6
April-September, 1903	11·57	5·67	2·55	·61	19·9
January-March, October-December 1904*	11·93	5·87	2·39	·56	20·7
April-September, 1904	10·86	5·54	2·45	·55	19·4

22733. Is it a "strong" sewage?—I should not describe the Manchester sewage as a strong sewage, except as regards its power of taking up oxygen from permanganate, which is largely due to trade effluents of a non-putrefactive character, more especially ammonia-recovery liquor. As regards actual sewage impurity it is weaker than many towns owing to the large sewage flow per head, averaging in dry weather between 40 and 50 gallons. It is really a somewhat dilute solution of domestic sewage in trade effluents and subsoil water.

22734. Does its strength vary very much from hour to hour or on different days of the week; and, if so, do these variations affect the quality of your final effluent to a marked degree?—The strength of the sewage varies a good deal from hour to hour, as is seen from the following figures, each of them representing the mean of a fortnight's analyses:—

Time.	4 Hours' Oxygen Test.	Chlorine.
	Parts per 100,000.	
1 a.m.	7·7	15·4
2 „	7·4	16·6
3 „	7·5	16·4
4 „	7·3	15·7
5 „	7·3	16·0
6 „	6·7	16·0
7 „	6·9	13·7
8 „	6·0	11·6
9 „	6·0	11·3
10 „	14·1	12·4
11 „	12·3	15·9
12 noon	10·6	16·0
1 p.m.	13·9	17·4
2 „	14·0	17·9
3 „	14·6	19·9
4 „	15·3	18·9
5 „	15·3	18·0
6 „	13·0	16·6
7 „	13·9	18·0
8 „	13·7	18·3
9 „	12·7	17·6
10 „	14·1	18·9
11 „	11·4	18·9
12 midnight	8·1	17·1

* Water supply limited for about six weeks during this period.

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The quality of the final effluent from septic treatment is not seriously affected, as the sewage is fairly well mixed in the tanks, but some difference is observed at different times of the day in the final effluent from beds which are supplied from sedimentation tanks. There is no great difference observable in the sewage on different days of the week, the less amount of trade effluent in Sunday sewage, for example, being partly compensated by the reduction in the volume and consequent greater concentration of the sewage. On the whole, however, Sunday sewage is distinctly weaker than the average.

22735. How do you think "strength" of sewage as affecting purification is best expressed or measured?—It appears to me that, on the whole, the strength of sewage is best measured by the number of gallons per head of population arriving at the works daily. Allowance must, of course, be made in the case of manufacturing sewage for the volume and character of the trade waste. The chlorine number when not affected by trade effluents is a good index. The ammonia figures give a better indication of the presence of real sewage than the permanganate tests.

22733. Have you any information as to the bacteriological condition of the sewage in dry weather and in storm times?—No; but samples have been supplied to Dr. Houston for investigation.

22737. Are there any chemical poisons in the sewage? If so, what are they, and to what extent do they occur?—At times acid tar is present, also phenols and compounds of naphthalene, as well as sulphocyanates, but none in sufficient quantity to prevent bacterial activity.

22738. Is the sewage always alkaline?—The sewage is practically always alkaline to methyl-orange, but not to phenol-phthalein.

22739. Do you find that the amounts of suspended solids are increased or diminished in times of storm, and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—The amounts of suspended solids are certainly increased in time of storm—at any rate during the earlier periods, as is seen from the following table of analyses of samples taken when the flow is at its height:—

Date.	Time.	Organic and Volatile.	Inorganic.	Total.
1903				
October 20th	6.0—9.0 a.m.	11·7	16·6	28·3
„ 23rd	6.15—9.0 a.m.	16·6	32·9	49·5
„ 28th	1.45—9.0 a.m.	21·1	42·0	63·1
„ 30th	6.30—9.20 a.m.	19·5	40·7	60·2
November 2nd	11.0 a.m.—1.0 a.m. (3rd)	22·0	28·4	50·4
„ 26th	7.15—11.0 a.m.	19·4	34·9	54·3
„ 28th	9.0—11.15 a.m.	12·9	18·6	31·4
December 8th	8.10—11.10 a.m.	26·5	35·1	61·7
1904				
January 13th	1.30—5.30 a.m.	19·7	45·1	64·5
March 14th	2.10.—3.50 p.m.	24·5	32·6	57·1
„ 29th	8.0—9.0 p.m.	46·8	54·8	101·7
„ 30th	8.50—10.20 p.m.	39·7	52·3	92·0
April 2nd		25·1	58·6	63·7
„ 6th	5.15—7.0 a.m.	28·0	48·3	76·3
„ 14th	4.0—7.20 p.m.	22·5	26·5	49·1
„ 15th	3.10—5 20 p.m.	16·5	21·7	38·3
„ 22nd	3.20—4.40 p.m,	88·9	169·5	258·3
„ 22nd	4.40—5.30 p.m.	51·5	120·0	171·4
May 2nd	3.0—5.10 a.m.	73·1	92·5	166·5
„ 27th	9.30—11.0 p.m.	61·5	112·8	174·3
„ 31st	5.0 p.m.—5.30 p.m. / 7.50 p.m.—1.40 a.m. } average	18·6	17·4	36·0
June 26th	12.30—2.0 p.m.	91·7	154·0	245·7
July 26th	7.10—10.20 p.m.	41·5	57·1	98·5
August 14th	4.0 a.m.—1.30 p.m.	12·8	22·0	34·8
„ 22nd	4.30—10.0 a.m. (23rd)	20·6	36·3	56·8
	8.30 p.m.—3.30 a.m.	6·8	11·4	18·3
September 3rd	4.30—9.15 a.m.	28·3	32·3	60·5
November 8th	8.25—11.25 p.m.	30·0	47·1	77·1
„ 9th	5.15—7.0 a.m.	10·5	21·1	31·7
December 16th	3.30—5.0 a.m.	52·0	88·6	140·5

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On the other hand, after a considerable period of rain the total suspended matter may be but little more than the average, and consist largely of mineral matter. This is seen from the following results obtained in 1896, when, it must be observed, the sewage of Manchester was very different from what it is at present :—

Time of taking Sample, October 6, 1896.	Oxygen absorbed 4 hours	Free Ammonia.	Albuminoid Ammonia	Chloride.	Suspended Matter.		
					Mineral.	Organic.	Total.
Dilute Sewage 3.30 p.m. - -	2·60	1·54	·46	6·9	—	—	—
Storm Water 5.30 p.m. - -	1·84	·40	·23	2·9	—	—	—
„ „ 7 „	1·51	·44	·06	2·4	43	10	53
„ „ 8 „	1·61	·43	·10	3·1	29	4	33
„ 9 „	1·77	·61	·08	4·6	63	4	67
„ „ 10 „	1·04	·61	·08	4·5	73	6	79
„ „ 11 „	1·03	·69	·09	7·0	40	13	53
„ „ 12 „	1·13	·83	·10	5·6	33	17	50

22740. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—A large number of results were published in the supplement to the experts' report published in January, 1900. The curve which I hand in is the result of a complete study of a long-continued storm on February 15th, 16th, and 17th, 1900, following a thaw. The diagram is self explanatory. (*See* diagram printed at end of Dr. Fowler's evidence, after p. 400). The composition of the settled sewage for week ending March 28th of the same year, which was a dry week, is indicated by the following numbers, stated in grains per gallon for the sake of comparison :—

Three minutes' oxygen test - - - 3·16
Chlorine - - - - - - - 12·8

The high figures for chlorine during the early part of the storm are due to the salt used for melting the snow.

22741. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions, up to a total of six, should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, very often found that the storm sewage which first comes down to the works contains a largely-increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—I think that unquestionably at least six times the *strict* dry weather flow (*i.e.*, as based on the water supply), and, if possible, more, should be treated in some way before entering a stream, but not necessarily by filters. It is exceedingly difficult in practice to say what should be dealt with by the ordinary plant and what by storm filters, as there is no necessary relation, unfortunately, between the volume and composition of the sewage, the first flush bringing down an enormous volume of foul sewage, to be followed, it may be, by a smaller volume of much less impure liquid. The instructions to the workmen at Davyhulme are that when a storm comes after a period of dry weather they are, as far as possible, to give one complete round of full treatment both on the storm beds and ordinary beds, after which the cycles may be shortened, and finally "streaming" resorted to. It is because of the great impurity of the first flush, large in volume though it may be, that I think as much as possible should be brought to the works. At any rate, the six times dilution should be calculated from the time of greatest daily dry weather flow, as this also coincides with the time of greatest impurity, as is seen from the following figures, taken at points near two typical overflows :—

	Rate of Flow.	Oxygen Absorbed.		Ammonias		Chlorine.
				Free.	Albuminoid.	
	Gallons per 24 hours.	4 hours.	3 minutes.			
A.						
Minimum - -	11,250	1·60	·70	1·50	·04	6·9
Maximum - -	29,500	10·70	6·30	9·43	1·40	19·4
Ratio - - -	2·65 : 1	—		—	—	—
B.						
Minimum - -	170,000	1·03	·46	2·21	·10	13·4
Maximum - -	590,000	13·83	6·40	8·86	1·83	19·7
Ratio -	3·47 : 1	—		—	—	—

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A certain amount of judgment should be allowed at the works as to what passes on to the filters, the endeavour being made to cope with the first flush, after which some may be let go, it being assumed that *all* passes through tanks. In general, no more suspended matter should pass away than is capable of being carried in suspension by the stream into which it is discharged. The addition of chemicals in time of storm I do not consider to be of much, if any, use, as the amount of suspended matter is already so great and the velocity of flow so increased that the chemicals have no chance of exercising any perceptible effect, and merely add to the amount of flocculent suspended matter. I do not think that settlement alone is sufficient for all the storm water coming down, unless it were possible, which in practice it is not, to impound and mix together the whole storm flow. No doubt a good deal of mud passes on to the beds in time of storm, but, on the other hand, they have afterwards to deal with weaker sewage, so that I do not know that, on the whole, much harm is done by the increased burden put upon them, it being understood that the average volume they are called upon to treat in wet and dry weather does not exceed that for which they are designed. Long-continued wet weather certainly puts them to a severe strain, and our experience suggests that if very rapid working is required the beds should be of a fairly open grade, simply in order to get the water rapidly on and off the beds. On the other hand, in this case the purification effected in dry weather will not be so good. But I am strongly of opinion that if foul deposits in sluggish streams are to be avoided, it is more important for authorities to make a serious endeavour to cope with as much as possible of the polluted storm flow than to obtain a superlatively good effluent in dry weather at the expense of letting a large proportion pass away untreated in time of storm. The limit of necessary expenditure should be carefuly considered in each case.

22742. With regard to storm overflows, do you think that the point at which they should come into operation should depend on the configuration of the land and upon the character of the surface soil geologically?—The engineer will give evidence with regard to that question, but I may say that I agree with his views.

22743. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case?—Yes; I think in all cases the conditions at the outfall should be carefully studied. The amount of impurity which can be discharged into a stream depends (a) on the power of the stream to carry matter in suspension; (b) the available dissolved oxygen in the stream. Thus there may be all gradations between, say, the Elbe at Hamburg, where no trace of sewage deposit can be found in the neighbourhood of the outfall when the tide is running out, and the Manchester Ship Canal, where only about 4 grains per gallon of solids can be carried in suspension in dry weather. In the first case also there is abundance of dissolved oxygen, in the latter case none in dry weather, though the conditions are in all respects improved in time of flood. These two conditions are not alone sufficient, however, where the stream has to support fish life or has to serve as a source of water supply. In both these cases the suspended matter carried by the stream is injurious, either owing to its clogging the gills of fish or blocking up waterworks filters. In such cases greater strictness will be necessary at the outfall.

22744. What are your views as to the necessity for treating road water in certain circumstances?—The engineer will give evidence on that point, but I may say that I agree with his views.

22745. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers, bearing in mind initial outlay as well as annual cost?—I am of opinion that the separate system is impracticable in large towns as at present existing in England. The first flush of the storm is so foul that it must be treated, and consequently large sewers must be made in any case, and no advantage arises from the great cost of duplication. In a well-designed and spacious garden city, with smooth, well-kept and well-sewered streets and few quarters where filth could accumulate, then it might be possible to provide a separate system with advantage, as the surface water would at no time be very foul. The same applies to villages and country districts where there is little traffic. There is no doubt that the treatment of the sewage at the outfall works is in such places enormously simplified, the great difficulty in sewage works management being to deal with the ever-varying volume and concentration of the sewage in wet weather.

22746. Is your sewage settled, and, if so, how—*i.e.*, by quiescent settlement or continuous settlement, and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—Yes; by continuous settlement, from three to four hours being taken in passing through the tanks. An average analysis of the tank liquor (weeks ending March 21st and 28th, 1905) is:—

Total suspended matter	= 6·5
Total mineral matter	= 3·0
Total organic and volatile matter	= 3·5
Four hours oxygen test	= 6·97
Three minutes' oxygen test	= 3·73
Ammoniacal nitrogen	= 2·02
Albuminoid nitrogen	= 0·26
Chlorine	= 17·0

(*See* also Manchester City Surveyor's report, 1896, pp. 26-27., Table XXVII.)

22747. Have you data to show what proportion of the suspended matter in your sewage is settled in ½-hour, 1, 2, 3, 4, 5, 6, 12, and 24 hours, if the sewage is given quiescent settlement?—Have not many data on this point as regards dry weather sewage. The following experiment made on February 3rd, 1899, shows that the greater part of the settlement takes place in 2½ hours:—

	Suspended Matter.		
	Total.	Mineral.	Organic and Volatile.
Original Sewage	33·6	14·9	18·7
After 2½ hours' settlement.	4·2	·9	3·3

22748. What time would be necessary for you to gain a good tank liquor containing, say, no more than six or eight parts of suspended solids per 100,000 from your sewage (without the addition of chemicals) by quiescent settlement and by continuous flow settlement?—The result obtained depends in each case on the amount of sludge present in the tank, *i.e.*, on the amount of settling space per given cubic content of tank. It also depends on the design of the tanks, but speaking very generally, my experience, both on the working scale and in the laboratory, would lead me to think that a tank liquor such as you describe could be obtained by two hours' quiescent settlement or by four hours' continuous flow.

22749. Do you prefer to use settlement tanks in series or in parallel?—Certainly in parallel.

22750. In the case of continuous flow tanks, do you think there is any advantage in the employment of baffling boards or walls?—Yes; the provision of baffling boards keeps back much of the floating grease which would otherwise pass on to the filter beds; also, if made pretty deep, they tend to prevent surface currents and consequent dead spaces in the tank. The provision of a submerged wall at the inlet may facilitate the separation of grit from the sludge proper, and render sludging easier, but it is of more value in the case of a septic tank, which is not so frequently emptied as a sedimentation tank.

22751. How is the sludging of tanks done at your works, and what is the character of the sludge? Does any nuisance attend the operation, and, if so, is it serious? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from your

tanks?—The sludging at the Manchester Works, Davyhulme, is mostly done by hand labour. The clear top water is first decanted by floating arms into an empty tank, if one should be available, or pumped back to the inlet channel. The water immediately over the sludge runs into the sludge well by the sludge channel, and is pumped back for retreatment. The sludge is then pushed by hand labour (men with squeegees) to the sludge penstocks, whence it flows by gravity along a channel to the ejectors which force it to the presses or into storage tanks, each capable of holding 1,000 tons, which are discharged by gravity into the sludge steamer, and sent away to sea. No serious nuisance attends the operation. There is some amount of smell if the sludge is stale. The men do not suffer, but it is far from pleasant work, and means have been tried to minimise hand labour.

22752. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—It depends upon circumstances. In general, most of the grit can be mixed in with the rest, and sent through the ejectors or sludge pumps. In Manchester the exceptionally large amount of cotton waste and other fibrous material in the sewage renders it necessary to screen the latter at the inlet to the works, otherwise the fibrous material would make it very difficult to screen the sludge. At Moss Side, which is a purely residential district, the sewage is not screened, but only the sludge, and even here frequent stoppages of the ejectors occur through blocking with waste, etc. On the other hand, I believe that sludge is very successfully screened at the Birmingham works.

22753. What is the manurial value of the sludge, and will farmers take it?—I have not a separate analysis of this sludge, but it will not differ greatly in Manchester from sludge produced by chemical precipitation. The farmers will take it in limited quantities.

22754. Are there any chemical poisons in it?—Without the addition of lime there is apt to be a development of acidity from the decomposition of fats.

22755. Do you find any nuisance from the treatment of sewage in settlement tanks? Have any complaints been made?—There is no nuisance, and no complaints have been made.

22756. Have you had experience of the chemical precipitation of sewage?—Yes.

22757. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—Excellent and well-nitrified filtrates have been obtained from all three liquids, according to circumstances. Much depends on the size of the filtering medium. I am inclined to think that, assuming the same amount of suspended matter in each case, and the same character of filtering medium, rather better results would be obtained by filtration of septic tank effluent. Unfortunately, strictly comparative experiments have not been made, but I base my opinion on the fact that much better results were obtained from septic tank effluent and double contact than from settled sewage and double contact. The greater uniformity of the septic tank effluent was probably partly accountable for this. Further, the coke and clinker experimental filters treating precipitated and settled sewage have never produced nitrates as in the case of the beds receiving septic tank effluent. On the other hand, it must be remembered that the above experimental filters contain a large proportion of coarse material.

22758. Have you tried various chemicals? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—I have had experience with various chemicals, viz., lime and copperas, ferric salts, and alumino-ferric, but have not gone very exhaustively into their various merits. Lime and copperas give a precipitate which readily settles, and the lime is useful where flushes of acid have to be neutralised. On the other hand, their use requires constant and skilled supervision, and is therefore less suited for small works than alumino ferric, where a given quantity can be added from time to time, and be left to dissolve in the incoming sewage. Ferric salts I have found not to give so rapid precipitation as either the lime and copperas or the alumino-ferric. The precipitate appears more finely divided than either of the others. Moreover, ferric salts, unless made on the works, are not readily obtained in a quickly-soluble and at the same time transportable condition. The following are prices per ton delivered at or near Davyhulme, showing that for equal weights lime and copperas are undoubtedly cheaper than alumino ferric:—

Lime	11/6
Copperas	21/6
Alumino ferric	40/-
Ferric sulphate	23/6

These prices will, of course, vary in different parts of the country.

22759. What is the most effective way of adding chemicals?—Where possible, I think that chemicals should be added in solution, with moderate mixing by baffling boards or otherwise, but not to such an extent as to break up the precipitate into a very finely-divided state.

22760. What is the average analysis of the liquor from your precipitation tank?—An average analysis of the effluent from chemical treatment for the quarter ending December, 1902, was:—

——	Parts per 100,000.
4 Hours' test, oxygen absorbed	8·57
3 Minutes' test, „ „	5·01
Ammoniacal nitrogen	2·43
Albuminoid „	·376
Chlorine	20·14

The suspended solids range from 2·0 to 6·0 parts per 100,000, consisting of about 60 per cent. mineral matter.

22761. What is the character of the suspended matter in such liquor?—The following are analyses by Mr. Scudder, in 1897, of suspended matter removed from the precipitated effluent by a mechanical filter:—

		I.		II.
Organic matter	—	38·0	—	45·8
Inorganic matter, consisting of silica and gangue	12·9	—	7·3	—
Oxide of iron and alumina	35·5	—	23·2	—
Calcium carbonate	13·6	62·0	23·7	54·2
	—	100·0	—	100·0

22762. Do you find it necessary to add further chemicals to the sludge before it can be dealt with? If so, for what reasons, and what chemicals do you use and how are they added?—Yes. Lime is added to the amount of about 2 per cent. on the wet sludge in order to obtain a coherent cake, which will come away from the presses. No doubt the lime acts largely mechanically, helping to bind the particles of sludge together. Also it will react with the fats and ammonia salts and neutralise any free sulphur which may be present. It is added to the liquid sludge in the form of powdery slaked lime. It is spaded in by hand, and is mixed by the mechanical agitation on its way to the presses.

22763. What is the manurial value of the sludge obtained by the chemical precipitation of the sewage,

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and will farmers take it?—The manurial value of the sludge is but slight, but the farmers take it in limited quantities, chiefly on account of the lime present. The following is an analysis of the pressed sludge cake by Mr. Scudder:—

	Per cent.
Moisture	56·4
Mineral matter	27·7
Organic matter	15·9
	100·0
Mineral matter consists of:—	
Lime CaO and $CaCO_3$	10·39
Iron and alumina	6·24
Insoluble	10·90
Phosphoric acid (P_2O_5)	0·17
Organic matter contains nitrogen equivalent to ammonia.	0·9

22764. Does the sludge contain any chemical poisons?—There is little difference between the sludge from chemical treatment and the sludge from settlement alone. The former seems to be rather less offensive, possibly owing to there being fewer free fatty acids present.

22765. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—There is no nuisance, and no complaints have been made.

22766. As regards septic tanks, how should they be shaped?—The shape of septic tanks must depend to some extent on conditions of site. On the whole, I prefer a long rectangular tank, so constructed that sludge can be removed both at the inlet and outlet end. In this way some differentiation of the sludge is possible, only the heavy gritty matter and the "worked over" fine deposit being removed, the bulk of the sludge remaining in the tank long enough for all possible digestion of solids to take place. Circular tanks have some advantage under certain conditions of site, *e.g.*, where there is greater possibility of depth than of extension, and the sludge can readily be removed automatically from time to time; but, on the other hand, it is not possible to differentiate the sludge to the same extent as in a rectangular tank.

22767. Should septic tanks be divided into sections?—It is certainly useful to provide at least a compartment both at the inlet and outlet ends of the tank to facilitate removal of sludge. Moreover, in certain cases where the number of persons connected to the tank is subject to great fluctuations, the smaller compartments may be used instead of the whole tank when the flow is very small.

22768. Should they be used in series or in parallel?—In parallel.

22769. Is a scum necessary or desirable?—I do not think the scum is necessary for bacterial action, but I think it is desirable in order to maintain equable conditions in the tank and to arrest floating fat.

22770. Should the septic tank be closed in, and, if so, what advantage does a closed tank possess over an open one?—I do not consider it necessary as regards septic action for a tank to be closed, and the sludging is facilitated by leaving it open. On the other hand, wind and rain have a disturbing effect on an open tank, and tend to break up the scum and allow pieces of it to pass away in the effluent. A closed tank is more sightly, and, where complaints of smell are likely to arise, is desirable, as it is possible to minimise the latter by the provision of shafts.

22771. What do you consider the best arrangement for the "feed" and "draw-off"?—The best arrangement for the "feed" and "draw-off" is, in my opinion, a long submerged cill, in front of which is some form of baffle plate so that a steady flow of sewage may be maintained through the body of the tank without wire-drawing.

22772. At what rate is sewage, as a matter of custom, passed through your septic tanks?—About 15 hours is taken by the sewage, as a rule, in passing through the tanks in Manchester.

22773. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous? Why do you consider one rate more advantageous than another? Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with?—The most advantageous rate of flow is largely a matter of circumstances. It may be roughly taken from available experience that with sewage of a strength of 40 gallons per head about 24 hours' flow is desirable, with a greater flow per head (the organic matter remaining the same) the rate may be correspondingly quicker and with a less flow less. Our knowledge on this subject is very imperfect. One may say, at any rate, that time must be given for settlement of the grosser solids and hydrolysis of the lighter suspended matter. Much, of course, depends on the length of travel in the sewer; with a long travel the simple hydrolytic changes will already be almost complete, whereas, on the other hand, in latrine sewage, the matter entering the tank may be practically in its original condition. There can be little doubt that the chief activity of the septic tank resides in the sludge, and this needs to remain in the tank a very long time for thorough digestion to take place.

22774. Is it possible to "over-septicise" a sewage, and, if so, for what reasons, and how is the "over-septicising" brought about?—Here again more exact information is required. It is certain, however, that prolonged retention of the sewage in the tank causes the evolution of sulphuretted hydrogen, and consequent production of nuisance. An effluent in which H_2S is present in quantity will rapidly take up oxygen, and it is for this reason probably that experience at Andover (Massachusetts) and elsewhere has shown that such effluents are not easily nitrified.

22775. What is the amount of digestion in your septic tanks, and how do you calculate this? How far do you find that the digestion is affected by the atmospheric temperature?—I hand in an extract from the Annual Report for 1901, from which it will be seen that experiments indicate that about half the organic suspended matter disappears in the septic tanks in Manchester. I may say, however, that the evidence is not as thorough as could be wished.

Extract from Annual Report for 1901.

MANCHESTER.

Bacterial Treatment of Raw Sewage.

The Work of the Open Septic Tank.

The early experiments with this tank are described in the experts' report of October 30th, 1899, and the report of the superintendent and chemist, January 16th, 1900.

Rate of Flo

During the later period of working the rate of flow through the tank was estimated to be equal to 2,500,000 gallons per day.

The flow through the tank was stopped on April 26th, 1900, or exactly 14 months from the beginning of the experiment.

Sludging o Tank.

By this time sludge had accumulated to such an extent that the effluent contained an excessive amount of suspended matter.

It was decided therefore to empty the tank.

A pump was fixed at the exit end of the tank, and the top liquid pumped out until the light sludge was reached. Pumping was then discontinued.

The valves leading to the sludge channels were then opened and the tank sludged in the ordinary manner.

Some difficulty was found in getting the sludge to gravitate down to the ejector chamber, and it was necessary to help it by addition of small quantities of water drawn through the floating arms.

Occasionally the ejector valves became clogged with rags and other floating substances. The presence of these was due to the fact that the sewage had not been screened before entering the septic tank, and

also that large quantities of garbage had been tipped in.

The sludge was very gaseous, and had a tendency to boil up on being disturbed. This occasioned some difficulty in taking it out to sea, some of the sludge frothing up through the vent holes in the tanks on the the deck of the sludge steamer. This difficulty, however, was got over by not filling the tanks quite full, thus allowing room for the sludge to swell.

Although the smell from the sludge was not disagreeable, the effect of the gases evolved, when breathed in a confined space, was to cause sleepiness, and, in some cases, nausea. These effects appear to be only temporary, but precautions should be taken to ensure thorough ventilation of closed tanks and subways where the sludge remains for any length of time.

The amount of sludge removed from the septic tank was equal in volume to 4,000 tons of ordinary sludge (*i.e.*, four boat loads were taken out to sea).

In addition, about 50 tons of detritus were tipped from the small settling tank which precedes the open septic tank. It was found that this material, on exposure to air, rapidly dried without causing a nuisance, and became similar to ordinary soil.

Average samples of the detritus and sludge were taken and analysed, with the following results :—

Detritus from Small Settling Tank.

Dried at 100 to 110 deg. C. and ignited.

Mineral matter - - -	78·7 per cent.
Organic and volatile matter -	21·3 ,,

Sludge from Open Septic Tank.

Dried at 100 to 110 deg. C. gave 85 per cent. moisture.

The dried residue on ignition gave—

Mineral matter - - -	56·5 per cent.
Organic and volatile matter -	43·5 ,,

Analysis of Mineral Matter.

SiO_2 - - - - -	36·76 per cent.
Fe_2O_3 - - - - -	30·17 ,,
Al_2O_3 - - - - -	18·63 ,,
CaO - - - - -	4·80 ,,
SO_3 - - - - -	4·73 ,,

The organic matter of the sludge consisted largely (more than one-half bulk) of bits of chaff, straw, and leaves, etc. On examination of some of the leaves under the microscope granular substances were discernible in the cells, showing that the disintegration was not complete.

Estimation of the Amount of Sludge which can be Destroyed by the Open Septic Tank.

In making this estimate, cognisance was taken of the following facts :—

(*a*) The open septic tank received crude sewage (*i.e.*, it had not passed through the screening chamber). The effect of this would be to increase the amount of mineral matter entering the tank above that likely to be obtained under working conditions.

(*b*) The bye-pass from the main sewer to the septic tank was taken off at a depth of 18 inches from the invert of the sewer. This would tend to reduce the amount of suspended matter entering the tank, below that obtained under working conditions.

(*c*) Several hundred barrow loads of garbage taken out in the screening chamber were tipped into the septic tank. Under working conditions this would be removed from the sewage before the latter enters the tank.

(*d*) The amount of suspended matter passing over the cill at the exit end of the tank was excessive during the later period of working. This matter must not, of course, be considered as having been destroyed.

(*e*) One or two direct measurements of the sludge deposited in the small settling tank were made. The mean of three determinations gave the result that 50,000 gallons of sewage deposited 400 gallons of sludge containing 84 per cent. of moisture. This is equal to about 40 tons of sludge (containing 90 per cent. water) per million gallons of sewage, or about twice the amount obtained in practice on the year's working. This tends to show that the sewage passing into the tank did not contain less than the normal amount of suspended matter.

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(*f*) The sludge obtained on cleaning out the septic tank was found to contain 85 per cent. moisture instead of 90 per cent., as is customary with ordinary sludge. In calculating the amount of sludge destroyed, the density of the residual sludge must be taken into account.

Allowing 20 tons of 90 per cent. sludge per million gallons, which is rather less than the average amount produced at the works during the years 1896, 1897, and 1898, and assuming the average flow through the tank at two million gallons per day, the total amount deposited by the ordinary method of treatment in 14 months would be 17,000 tons ; as 4,000 tons only were obtained, it might be concluded that upwards of 75 per cent. had been destroyed.

The general effect of the various circumstances mentioned above would be, however, to decrease this estimate, and it was provisionally concluded that a destruction of from 50 to 60 per cent. had taken place.

Provisional Estimate.

In making this estimate there were, however, several undetermined factors.

Undetermined Factors.

It was necessary to know more accurately—

1. The rate of flow through the tank over a prolonged period.

2. The actual amount of suspended matter, both mineral and organic, that was passing into the tank.

3. The amount of suspended matter, both mineral and organic, passing away from the tank.

4. The actual weight of suspended matter, both mineral and organic, left in the tank after a period during which the above measurements had been carefully made.

5. The amount and nature of the dissolved matter entering and leaving the tank.

6. The amount of iron in solution and suspension entering and leaving the tank.

7. The amount of gas evolved from the tank.

The tank was restarted on May 16th, 1900, and in the following paragraphs are given the results of the measurements which have been made :—

1. Rate of Flow through the Tank.

The exact determination of the rate of flow through the septic tank has been a matter of considerable difficulty owing to the unevenness and thickness of the cill over which the tank effluent flows.

A number of measurements were taken of the depth of flow at various points along the cill, and thus an approximate estimate could be made of the average rate of flow over the whole of the cill.

During the earlier part of the experiments measurements were made on four occasions. From these the average flow from May 16th, the date on which the tank was started, to November 14th, the date of the first determination of sludge in the tank, was estimated at 2,500,000 gallons per day.

Latterly, from December 13th to January 24th, the date of the second determination of sludge, measurements of the depth of flow over the cill have been made hourly.

From these the rate of flow from November 14th, 1900, to January 24th, 1901, has been estimated at 2,000,000 gallons per day.

The following observation tends to show that these estimates are, at any rate, not excessive.

On May 10, 1900, when the septic tank was restarted, it was found that it could be filled from the bye-pass running full bore in 7·3 hours. The capacity of the tank is 1,125,000 gallons, so that this time of filling represents a rate of flow of 3,600,000 gallons per day.

2. Suspended Matter Entering Tank.

The septic tank is supplied with sewage by means of a bye-pass from the main sewer. It is therefore of interest to determine whether the sewage entering

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the septic tank contains as much suspended matter as the main bulk of sewage passing through the works.

For this purpose comparative analyses were made, which are summarised in the following table :—

Average of daily samples made up of equal portions of hourly samples.

Sewage sampled at Sewer Head.	Sewage sampled at Inlet to Open Septic Tank.
Mean of 28 determinations from August 1st, September 28th, 1900, gave 25·94 grains per gallon.	——
Mean of 11 determinations from October 2nd to October 31st, 1900, gave 27·78 grains per gallon.	Mean of 19 determinations from October 2nd to October 31st, 1900, gave 26·34 grains per gallon.

The above determinations show that the composition of the sewage was practically identical in the two cases.

Determinations have also been made to ascertain to what extent these numbers are affected, according as the sampling is proportional or otherwise to the rate of flow.

For this purpose two daily average samples of sewage were made :—

I.—Of hourly samples mixed in equal volumes.

II.—Of hourly samples mixed in volumes proportional to the rate of flow as recorded automatically in the main sewer.

I.

Period.	No of Samples.	Mean Suspended Matter. Grains per gallon.			Minimum.			Maximum.		
		Mineral.	Organic.	Total.	Mineral.	Organic.	Total.	Mineral.	Organic.	Total.
Oct. 2nd to Oct. 31st, 1900 - - - -	19	14·5	11·8	26·3	6·7	8·6	15·3	23·0	16·3	39·3
Nov. 14th, 1900, to Jan. 24th, 1901 -	49	13·5	12·1	25·6	6·0	8·0	14·0	35·0	20·0	55·0

II.

Period.	No. of Samples.	Mean Suspended Matter. Grains per gallon.			Minimum.			Maximum.		
		Mineral.	Organic.	Total.	Mineral.	Organic.	Total.	Mineral.	Organic.	Total.
Oct. 2nd to Oct. 31st, 1900 - - - -	15	17·1	13·0	30·1	8·7	8·7	17·4	31·0	20·8	51·8
Nov. 14th, 1900, to Jan. 24th, 1901 -	47	16·1	14·0	30·1	10·4	7·7	18·1	46·2	28·4	74·6

The above results show that by mixing the hourly samples in volumes proportional to the rate of flow of sewage an average sample is obtained, containing 4·1 grains per gallon more suspended matter than when they are mixed in equal volumes.

This difference is chiefly to be accounted for by the excessive amount of suspended matter brought down in time of storm.

During the ordinary dry weather flow the average difference is hardly appreciable.

The rate of flow of sewage through the septic tank was not conditioned solely by the volume of sewage passing through the main sewer, although this affected it to some extent.

In the following calculations the lower of the above numbers has been taken as the amount of suspended matter entering the tank. Any error thus introduced would tend to minimise rather than to exaggerate the work done by the tank.

3.—Suspended Matter Leaving the Tank.

The effluent from the open septic tank was sampled hourly, and an average of these samples made from noon to noon.

Period.	No. of Samples.	Mean Suspended Matter. Grains per gallon.			Minimum.			Maximum.		
		Mineral.	Organic.	Total.	Mineral.	Organic.	Total.	Mineral.	Organic.	Total.
Aug. 2nd to Oct. 31st, 1900 - - - -	39	6·9	4·1	11·0	2·60	·65	3·25	10·55	8·45	19·00
Nov. 14th, 1900, to Jan. 24th, 1901 -	36	7·55	3·75	11·3	5·20	1·80	7·00	11·00	4·80	15·80

It should be noted that from time to time suspended matter was observed to pass away in the septic tank effluent in small lumps, although this was obviated as far as possible by a screen of wire netting. Some amount of suspended matter may have escaped collection in the samples owing to this cause, but the portion thus lost can only have been small.

4.—Suspended Matter Remaining in the Tank.

The amount of suspended matter contained in the tank was determined on November 14th, 1900, by the following method:—

Sections of the tank were taken by means of a glass tube 1 in. diameter and 7 ft. long, which could be closed at the bottom by a rubber ball attached to a piece of string which passed through the whole length of the tube. The tube was in two lengths, joined by wide india-rubber tubing; the ends of the tube were provided with brass collars, the whole being mounted on a narrow board, which was marked for convenience in divisions of 6 in.

Four sections were taken along both the inlet and exit ends of the tank, and six up either side, making 20 sections in all.

The contents of the tube in each case were run into a bucket, and the whole of the samples thus obtained mixed together, giving an average sample of the tank.

The suspended matter contained in this average sample was 3624·6 grains per gallon, which is equal to 231·2 tons per million gallons, of which 60 per cent. was found to be mineral matter.

As the capacity of the tank is 1,125,000 gallons, the amount of suspended matter contained in it was 260 tons.

On September 12th and 13th, 1900, about 30 tons of wet sludge were removed from the small settling tank preceding the septic tank, and at the time of this determination there was a similar amount remaining in it, so that to the 260 tons in the septic tank must be added 60 tons of wet sludge, which at a liberal estimate would represent 30 tons of dry suspended matter.

The total quantity of suspended solids therefore remaining in the tank was 290 tons.

A second section was taken in a similar manner to the above on January 24th, 1901, with the following result:—

The suspended matter contained in the average sample was 4352·8 grains per gallon, amounting to 313·5 tons suspended matter in the tank, of which 60 per cent. was found to be mineral matter.

The small settling tank preceding the septic tank was not cleaned out during this latter period.

Calculation of Work done by the Tank.

From the above data the following figures have been calculated:—

I.—Period from May 16th to November 14th, 1900.

Total flow of sewage through the tank during this period	425 million gallons.
Suspended solids entering the tank	707 tons.
Suspended solids leaving the tank	264 ,,
Amount deposited in the tank	443 tons.
Amount found in the tank, including silt	290 ,,
Total suspended solids disappeared	153 tons.
	= 21·6 per cent. of total suspended solids in sewage.
Total suspended solids to be dealt with as sludge and silt	290 tons.
	= 41·0 per cent. of suspended solids in sewage.

II.—Period from November 14th, 1900, to January 24th, 1901.

Total flow of sewage through the tank during this period	142 million gallons.
Suspended solids entering the tank	233 tons.
Suspended solids leaving the tank	102 ,,
Amount deposited in the tank	131 tons.
Actual amount found in the tank	53 ,,
Total suspended solids disappeared	78 tons.
	= 33·5 per cent. of total suspended solids in sewage.
Total suspended solids to be dealt with as sludge and silt	53 tons.
	= 23 per cent. of total suspended solids in sewage.

III.—Total period from May 16th, 1900, to January 24th, 1901.

Total flow of sewage through the tank during this period	567 million gallons.
Suspended solids entering the tank	940 tons.
Suspended solids leaving the tank	366 ,,
Amount deposited in the tank	574 tons.
Amount found in the tank, including silt	343 ,,
Total suspended solids disappeared	231 tons.
	= 24·6 per cent. of total suspended solids in the sewage.
Total suspended solids to be dealt with as sludge and silt	343 tons.
	= 36·5 per cent. of total suspended solids in sewage.

On April 30th, 1901, the sludge had attained a depth of 2 ft. 6 in. at the exit end of the tank. It was therefore decided to empty the tank, with the exception of a quantity of sludge sufficient to re-start septic action when the tank was again working. Tank emptied.

The tank was sludged in the ordinary manner, and a quantity equal in volume to 2,500 tons of sludge of 90 per cent. moisture was sent to sea without difficulty.

This sludge, however, contained on the average only 83 per cent. of moisture. Of the solid matter, 60 per cent. was mineral.

The increased density of septic sludge is an economical factor in the working of septic tanks, as the cost of removal of sludge is conditioned rather by its volume than its weight. Had the sludge contained 90 per cent. moisture its volume would have been equivalent to 4,250 tons. Density of Septic Sludge.

Besides the sludge, properly speaking, a certain amount of water containing much black suspended matter was run into a neighbouring tank for further treatment with the ordinary sewage. This was done by means of the floating arms in the tank, without having recourse to pumping.

The quantity of sludge remaining in the tank was estimated liberally at 1,000 tons.

It may be concluded, therefore, that after 11 months' working a volume of sludge remained to be dealt with equal to 3,500 tons.

Allowing an average daily flow through the tank of 2,000,000 gallons for 334 days of working, the sludge produced by chemical treatment would have amounted to 9,045 tons, allowing only 13·5 tons per million gallons.

The result obtained by the careful measurements recorded in the foregoing paragraphs is thus confirmed, viz., that rather more than one-third of the total suspended solids in the sewage will have to be dealt with as sludge in the septic tank.

During the course of emptying the tank the experiment was tried of pressing about 100 tons of the sludge

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Pressing of Septic Sludge.

with lime. No difficulty was experienced in producing a firm pressed sludge cake containing about 50 per cent. moisture.

5.—The Amount and Nature of the Dissolved Matters

A series of determinations have been made of the amount of dissolved matter entering and leaving the tank, by evaporating known volumes of the sewage and effluent after filtration through paper, and weighing the solid residue.

An average of six determinations (confirmed by similar observations in connection with the closed septic tank) gave the following results:—

Grains per gallon.

Raw Sewage.			Open Septic Tank Effluent.		
Mineral.	Organic and Volatile.	Total.	Mineral.	Organic and Volatile.	Total.
33·0	33·0	66·0	30·8	25·0	55·8

A certain amount of loss of ammonia as ammonium carbonate will take place on evaporation in both cases, and this will probably be greater with the septic tank effluent.

An examination of the residue obtained by evaporating large quantities of open septic tank effluent (filtered through paper) shows that the mineral matters largely consist of iron oxide, from the decomposition of organic compounds of iron, and calcium sulphate. Among the volatile constituents have been detected ammonium carbonate, mercaptan-like compounds of very offensive smell, acetic and butyric acids. No evidence of the presence of amines could be found in the residue on evaporation, but by distilling large volumes of the liquid and carefully analysing the platinum salts obtained from the distillate the presence of amines was indicated.

Research in this direction is being continued; careful comparison especially will be made of the products obtained by evaporation and distillation of crude sewage and septic tank effluent respectively.

The evidence, however, points to a breaking down of albuminoid and cellulose matter in the septic tank into simpler and to some extent volatile compounds. The reactions are probably hydrolytic in character, ammonia, amines, carbonic acid, water, and possibly alcohol being produced.

A further quantity of organic matter also disappears as methane, nitrogen, and hydrogen (see section 7).

6.—The Amount of Iron Entering and Leaving the Tank.

As Manchester sewage contains considerable quantities of iron pickle (ferrous chloride), it is of importance to determine the amount of insoluble iron deposited in the tank, and also to ascertain what quantity passes away either in suspension or solution in the effluent, and thus on to the bacteria beds.

The iron in solution was determined in each daily sample (mixture of hourly samples) of sewage and septic tank effluent by filtering through paper and boiling the filtrate with a little nitric acid. A known quantity (generally 35 c.c.) of the oxidised solution was treated with sulphuric acid (one part acid to two of water) and excess of potassium sulphocyanate, and the amount of iron determined colorimetrically by comparison with a standard iron solution.

The iron in suspension and solution was also determined in a weekly average sample obtained by adding 100 c.c. of each daily sample to a half Winchester bottle.

The iron in solution in this sample was determined as above.

The iron in suspension was obtained by filtering 140 c.c. through paper, drying and igniting the suspended matter, and fusing with fusion mixture. The mass was extracted with dilute hydrochloric acid and boiled with a little nitric acid. This solution was made up to 500 c.c., and the iron determined colorimetrically as above.

The results (expressed in grains of iron per gallon) are given on the opposite page:—

Table showing Amount of Iron Entering and Leaving Septic Tank

	Iron in Solution determined in daily average of hourly samples.			Iron in Solution determined in weekly average of daily samples.			Iron in Suspension determined in weekly average of daily samples.		
	Raw Sewage.		Open Septic Tank Effluent.	Raw Sewage.		Open Septic Tank Effluent.	Raw Sewage.		Open Septic Tank Effluent.
Date 1900.	Hourly samples mixed in equal proportions.	Hourly samples mixed in proportion to flow.	Hourly samples mixed in equal proportions.	Hourly samples mixed in equal proportions.	Hourly samples mixed in proportion to flow.	Hourly samples mixed in equal proportions.	Hourly samples mixed in equal proportions.	Hourly samples mixed in proportion to flow.	Hourly samples mixed in equal proportions.
December 11th	·24	—	·56						
,, 12th	·47	·40	·94						
,, 13th	·30	·56	·56	·19	·284	·50	4·20	4·0	1·48
,, 14th	·61	·77	·65						
,, 15th	·18	·16	·28						
Average	·36	·47	·60						
December 18th	·61	·50	·74						
,, 19th	1·18	·59	1·18						
,, 20th	·12	·40	·14	·48	·23	·55	5·00	5·20	2·22
,, 21st	·72	·50	·67						
,, 22nd	·55	·56	·57						
Average	·64	·51	·66						

These numbers (which have been confirmed by other similar determinations) show clearly that while there tends to be more iron in solution in the septic tank effluent than in raw sewage, there is considerably less in suspension. There must therefore be a gradual accumulation of insoluble iron compounds, for the most part ferrous sulphide, in the septic tank.

Less iron is found in solution in the weekly average of the septic tank effluent than when analyses are made daily, owing doubtless to a certain amount of oxidation on standing.

This indicates that the iron in solution in the septic tank effluent will be deposited when oxidation takes place in the bacteria bed. Analyses show that no dissolved iron is present in a good sample of filtered effluent.

It has been found that the presence of much dissolved iron in a filtrate may, in general, be taken as an indication of imperfect aeration in a bacteria bed.

Condition of Dissolved Iron in Septic Tank Effluent.

The above experiments having shown that there was a tendency for iron compounds to enter into solution in the septic tank, it was of interest to determine whether these were actually dissolved or whether they were present in the colloidal condition, or, as it is sometimes termed, in a state of pseudo-solution.

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For this purpose a series of determinations were made of the iron present in the open septic tank effluent after this had been filtered through paper and through a Kitasato sterilising filter respectively.

The filtration through the sterilising tube was accomplished by fixing about an inch of this tube into the neck of a glass filter-funnel by means of india-rubber tubing. The funnel was in its turn similarly fixed into the top of a tap funnel of about 300 c.c. capacity, to the lower end of which a tube about 25 inches long was attached. By filling the tap-funnel and tube with mercury, suction could be applied to the filter-funnel, and in this way liquid enough for analysis was drawn through the sterilising tube.

The following numbers are the mean result of the colorimetric determination of iron in nine samples of open septic tank effluent filtered through paper and through the sterilising tube respectively:—

Iron (Fe) in grains per gallon.

Effluent filtered through paper.	Effluent filtered through Kitasato tube.
·52	·21

It appears therefore that some portion of the iron is present in a true state of solution, probably combined with certain organic acids. It is intended to further investigate this point by submitting fairly large quantities of sewage and septic tank effluent to dialysis.

7. Gas Evolved from Open Septic Tank.

A circular sheet-iron gasholder, three feet in diameter, was suspended in the septic tank, and careful record made of the rate at which it rose.

From these measurements it was estimated that when the tank is in full activity about one cubic foot of gas was evolved from 100 gallons of sewage. From 30,000,000 gallons of sewage this amounts to 300,000 cubic feet, or six tons of gas per day. This would be equal in heating power to about eight tons of coal.

Approximate analysis of the gas gave the following numbers:—

CH_4	73·0 per cent.
CO_2	6·0 ,,
H.	5·0 ,,
N. (by difference)	16·0 ,,

General Observations and Conclusions.

1. The results show clearly that a greater amount of destruction goes on during the later period of the action of the tank, after septic conditions have become matured.

2. The experiments also show the importance of working the tank lightly during the earlier stages. In the second run of the tank, beginning on May 16th, 1900, the flow was evidently rather excessive, as it was about two months before active septic action commenced, and during this time a considerable amount of sludge accumulated.

3. In considering the work of the septic tank during the second period reported, it should be noted that the weather during a large part of the time was exceptionally wet, the storm water bringing with it considerable quantities of silt. In addition to reducing the capacity of the tank, it is possible that so much inert matter may to some extent prejudicially affect the septic action.

4. As a general result of the above experiments, especially those recorded in section 4, it appears likely that a system of septic tanks having a capacity equal to half the daily flow of sewage, is capable in Manchester of liquefying or converting into gas about 25 per cent. of the total suspended matter. Rather more than a third will require to be dealt with as sludge. The remainder will be partly oxidised on the bacteria beds, and partly require to be removed from their surface as soil. If this is done in dry weather the actual bulk to be removed should not be excessive.

5. It should be pointed out that the work of the septic tank is not confined to the destruction of sludge, but it is also of great use: (1) in obtaining an effluent of more equable composition for treatment on the bacteria beds, and (2) in producing an effluent readily capable of nitrification. (See Experts' Report, October, 1899.) Work of Septic Tank.

6. Although it is questionable whether the amount of gas given off from the open septic tank in Manchester is likely to be of sufficient value to repay the cost of collection, yet it is worthy of suggestion that in cases where for sanitary or other reasons it is desirable to cover the tank, the utilisation of the gas may afford some off-set to the cost of such covering. Gas evolved.

7. The fact that some time must elapse before septic action attains a maximum indicates the importance of adopting some form of tank which will permit of the removal of sludge from time to time without interfering with the action of the tank as a whole. A tank arranged on these lines has been constructed, and is now in operation. Construction of New Septic Tank

It is hoped also that this tank will permit of efficient septic action taking place, while at the same time it will retain a large amount of fine suspended matters which would otherwise pass on to the bacteria beds.

The results will be reported upon in due course.

As far as can be judged by the rate of evolution of gas, the digestion is more rapid in warm weather.

22776. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?—Undoubtedly it is better to remove a certain amount periodically, say once a month, or as often as is needed to keep the sludge below a certain level in the tanks.

22777. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—The sludge should be forced out of the tank automatically by the pressure of the water. Hand labour should be avoided as far as possible, especially in confined space, as a good deal of gas is evolved from the moving sludge which, although not very offensive to smell, may produce nausea and headache in those working in the midst of it continually. Precautions also must be

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taken in sludge galleries to use only electric light or safety lamps, as there may be risk of a flare of marsh-gas. The evolution of gas, however, is much less if the sludge is removed periodically and in such a way that half-digested sludge is left in the tank as far as possible. As to the disposal of the sludge, it can be sent to sea, the same precautions being taken as above. In addition it has been found advisable to mix a certain proportion of sea water along with the sludge in the steamer sludge tanks ; in this way fermentation en route can be largely prevented. Septic sludge can also be pressed with lime, rather a larger proportion being used than in the case of sludge from chemical treatment or sedimentation. A certain proportion can be disposed of to farmers at such times as the land requires manure. In small places the sludge can be lagooned and air-dried on simply constructed cinder beds. The operation need not be offensive, and the dried sludge can be sold to farmers, especially if mixed with lime. The addition of lime is desirable in any case to prevent the formation or neutralise the effect of free sulphur which may be produced on oxidation of the sludge.

22778. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank? —Yes.

22779. What amount of suspended solids, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—The following are typical figures showing variations in suspended matters :—

Period.	Organic and Volatile.	Mineral.	Total.
Average for the 1st month	2·0	1·0	3·0
„ next 2 months	3·1	2·3	5·4
„ next 2 months	4·1	3·1	7·2

Solids may increase to 10 or 14 parts per 100,000 if sludge is not removed.

22780. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—A portion only, but not the whole for the reasons—

(1) There is liable to be an undue quantity of suspended matter passed away from the tanks in the early stages of the increased flow, especially if the tanks are fairly full of sludge to begin with.

(2) The effluent tends to become merely settled sewage, and to remain so for some time after the increased flow, so that the results from the subsequent filtration deteriorate somewhat.

(3) The filters are liable to be overworked.

My experience indicates that a two to one dilution is as much as can with advantage be put through septic tanks and on to the filters accustomed to septic tank effluent ; beyond this dilution the sewage should be put through settling tanks and on to the beds reserved for storm water.

22781. If storm sewage is passed through a septic tank does this cause an increase in the amount of suspended solids issuing from the tank, and if so, can you give us figures (in parts per 100,000) showing what the increase is?—In the early stages of the increased flow there is no doubt that the suspended matter is increased largely by portions of floating scum, etc., which are broken away. This is readily seen by the condition of the surface of the beds. Afterwards, however, the effluent contains less suspended matter than usual. I have no exact figures on this point.

22782. May you admit storm sewage to your septic tank to an extent which raises the ordinary level of the liquid, without serious detriment to the functions of the tank?—I see no reason why this should not be done within limits. I am aware of cases where this method obtains with ordinary sewage, the object being to obtain a head and a measured quantum of liquid to discharge on to a filter. This does not seem to disturb the working of the tank, and so long as the admission and discharge of storm water is effected with the minimum of disturbance of the tank contents I see nothing against the suggestion.

22783. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—Much more information is needed on that point. The extract from the annual report for 1901, which I have handed in, gives the results of some observations which have been made in Manchester in regard to matters in solution in septic tank liquor. Observations have recently been made, and are in progress, by means of dialysis to determine if possible in more detail the nature of the changes going on in the septic tank, but there are not enough data to generalise upon.

22784. Have you any data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints?—No, save that certain experiments have been tried with strainers at the exit to septic tanks, which tend to show that such devices are liable to become choked with growths of sphærotilus, etc.

22785. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—The chief trouble is the gas evolved from the sludge in the sludge gangways when emptying the tanks. This can be to a large extent obviated in the way I have already suggested. There is very little smell from the tanks themselves. In close, muggy weather some slight odour is apparent, and is remarked by workmen, but it is not serious. No complaints have, to my knowledge, been made. It must be remembered, however, that the iron salts in Manchester sewage no doubt practically prevent the evolution of sulphuretted hydrogen.

22786. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—Unless the filter is specially constructed with a view to the aerobic digestion of as much as possible of the suspended solids, it is probably economical to keep the greater proportion of these off the beds. The economical limit will vary in different places. Thus, where the area of filters is necessarily limited, it may be better to spend more in chemical treatment or otherwise to produce an effluent as free as possible from suspended matter. On the other hand, where the area of beds is not so restricted it is cheaper to spend less in this way and wash or renew the material of the beds at long intervals. By the latter method the maximum reduction in the volume and weight of sludge is effected. Unless, however, some special form of construction is used the economical limit in this case is about 11 parts per 100,000. With more than this the labour in keeping the surfaces of the beds open becomes excessive.

22787. In what way can the removal of suspended solids best be effected?—This can be done, at a price, by thorough chemical precipitation. Small doses of chemicals do not effect much more than simple sedimentation or treatment in septic tanks. Whichever of these methods is adopted it is important that the tank be designed carefully to effect the greatest settlement in a small space, and that the sludge be not allowed to accumulate beyond a certain critical depth.

22788. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?—Yes, I have experimented with various forms of strainers and with an automatic self-cleansing filter, and my general conclusion is that if any such device is successful in removing suspended matter, it is only at the cost of very frequent washing. If it allows the effluent to pass through rapidly, then fine suspended matter also passes with it. There is the further difficulty in using anything of the nature of a strainer for sewage or effluents that growths of sewage fungus tend to form and clog the filter and foul the effluent.

22789. What other, if any, method of dealing with tank liquor before delivering it to filters do you regard as necessary or desirable?—It is possible to remove the greater part of the visible suspended matter from the effluent before passing on to contact beds by covering a portion of the surface with a thin layer of fine material, either small clinker or gravelly sand. Such a method in the case of a continuous filter converts the latter into a "controlled filter," a form of continuous filter, which, in my judgment, has best stood the test of time.

22790. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement. I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis. The different methods of settlement of which I should like to hear your views are quiescent settlement without chemicals, quiescent settlement with chemicals, continuous flow settlement with and without chemicals, and septic tank treatment?—It is exceedingly difficult to give a precise answer to that question, as circumstances and conditions vary so greatly in different places. I hand in a tabular statement, in which certain main considerations affecting the choice of one or other method are given in outline. It has hardly seemed practical to make the suggested comparison by reducing the sewage to the same figure for suspended solids, as in practice one or other method would be chosen according as the conditions made it more economical to reduce the matters going on to the filters, and consequently obtain more sludge, or vice versa. Assuming that it were practical to obtain a tank effluent containing the same amount of suspended matter by the various methods suggested, then the filter costs would be brought more nearly equal, but these are also conditioned by the presence of colloidal matter in what may be termed pseudo-solution, the amount of which is not arrived at simply by the ordinary methods of determining suspended matter. An instructive example of the effect of local conditions in determining the method to be adopted is afforded by the respective works of Manchester and Salford. In Manchester a fairly large area is available for filters, but little depth, and the whole of the sewage arrives at the works by gravitation. At Salford most of the sewage has to be pumped, and the area available for filters is very limited. Therefore, open septic tanks and contact beds have been chosen for Manchester, and heavy chemical treatment followed by "roughing filters" and deep percolating filters for Salford. Again, while little or no nuisance is likely to arise from open septic tanks in Manchester, where the iron present in the sewage fixes the sulphuretted hydrogen to a great extent, it would be unwise to recommend open septic treatment for Withington, where a purely domestic sewage has to be dealt with not far from a thickly-populated residential district. Further, certain sewages, *e.g.*, at Bradford, may contain manufacturing refuse of such a nature that preliminary chemical treatment is necessary before attempting biological purification by any method.

22791. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—In cases where there is a good sound clay subsoil, or even in some cases loamy clay, beds may be successfully built without any concrete, and do good work for years, *e.g.*, especially Oldham and Burnley. Rather more area is required for banking in this case, so that it may be better in some cases—*e.g.*, in many of the storm beds in Manchester—to use concrete for the walls and as a foundation for the "drains," and leave the rest of the bed bottom the natural earth.

22792. Do you find that within certain limits the depths of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—Yes; I have seen contact beds successfully at work varying from 15 in. in depth (Manchester experimental bed) to 13 ft. (London). The limit in both cases depends simply on conditions of drainage. With a very shallow bed (say 6 in.) the drains would take up too much of the contact space; with a depth beyond 4 ft. care must be taken that hard and fairly large material is used, or there may be crushing and excessive capillary attraction, preventing free aeration and drainage.

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22793. What do you consider is the most convenient size for a contact bed?—The actual size obviously depends on the quantity of effluent to be dealt with. Probably an acre is about the largest size that can be conveniently worked as one unit. The number of units in a given installation depends upon circumstances, but each unit should not be so large that the time taken to fill the bed at the time of minimum flow will seriously shorten its resting period. The least number of units which can be worked to prevent this result is eight, unless some form of impounding or dosing tank is employed, which is a useful device in small installations.

22794. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—The experience in Manchester has been that hard furnace clinker is the best material, being vesicular and yet permanent. Preliminary washing and selection produces a better material than simple screening, but increases the cost unduly. After five years' use the material may be taken out and washed at a small cost, and then a naturally selected material obtained, of better quality than could have been produced by washing and selecting the original clinker. Other localities may not be able to obtain hard clinker, or may be able to obtain other material, *e.g.*, broken Staffordshire bricks, broken "saggars," gravel, more cheaply than in Manchester. If properly sized, these materials should do equally as well as clinker.

22795. What size should the filtering material be, and should it be graded in the beds?—This depends entirely on what result is required. Within limits, the finer the material the better the result. Probably the best qualitative and quantitative results taken together are obtained when the size is such as to afford the maximum of surface combined with the maximum air supply. A different size will therefore be required in a primary bed from what is suitable for a secondary bed, as the interspaces will be less quickly filled in the latter case. In general, the more organic matter (suspended and colloidal) there is present the larger should be the material. The limit of fineness is probably about $\frac{1}{8}$ in.; less than this tends to water-logging, unless only very small doses are put in or the effluent applied contains but little impurity. Systematic grading is not, in my view, necessary for a contact bed. The only essential is that there should be sufficient coarse material at the bottom to effect good drainage. A small amount of material, finer than the main bulk, on the top to effect distribution over the surface of the bed and arrest coarser suspended matters is of some advantage, though it increases the routine labour on the bed, especially in wet weather. Whether it materially increases the time during which the bed will work without taking out the material is not at present quite certain.

22796. How should the bottom of the bed be constructed?—The bottom of the bed should be constructed to effect the freest possible drainage in the most economical manner. Sunk drain channels formed in concrete and covered with perforated tiles over which are placed plenty of large clinkers—or, better, big flints from gravel—are very efficient. Except, perhaps, in the case of secondary beds, however, these should not be left full while the bed is resting, as the liquid left in tends to become foul and fungoid growths are apt to form.

22797. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—Yes, unless the beds are specially constructed to effect the aerobic digestion of sludge. It has yet to be shown that in many cases where there are difficulties in dealing with sludge from tanks and where freedom from nuisance is essential, a purely aerobic method is not desirable, and possibly even economical. With present experience tank treatment appears to be rather less costly and troublesome.

22798. What periods of filling, standing full, emptying, and standing empty do you consider best in prac-

TABULAR STATEMENT HANDED IN BY DR. FOWLER AND REFERRED TO IN 22790.

	QUIESCENT SETTLEMENT WITHOUT CHEMICALS. I.	QUIESCENT SETTLEMENT WITH CHEMICALS. II.	CONTINUOUS FLOW SETTLEMENT WITHOUT CHEMICALS. III.	CONTINUOUS FLOW SETTLEMENT WITH CHEMICALS. IV.	SEPTIC TANK TREATMENT. V.
NUISANCE	In hot weather may rapidly sour and tend to nuisance.	No danger of nuisance.	Tendency to become septic, if not frequently sludged.	No danger of nuisance with reasonable care.	Possible nuisance if uncovered or if flow too small for tank space.
SLUDGE REMOVAL	Likely to obtain liquid and possibly sour sludge.	Large volumes of sludge obtained.	Sludge may be rather more offensive than in IV.	Most dense sludge produced by this method.	Sludge must be removed with precautions as stated in reply to 22777.
PURIFICATION OF TANK LIQUOR.	Large variations in composition of effluents at different times of day, more filter space required than II. or IV. Tendency to septic action increases variability of results.	Some variation in strength of effluent at different times of day, but on the whole requires least filtering area of any method.	More equable effluent than I. or II., but requires more filtering area than either of these.	Same as III., but requires less filtering area.	Most equable effluent with good management can often get well nitrified effluent with single contact.
ANNUAL COST	Cost of pumping out of tanks more than III., IV. or V. unless considerable fall available. Cost saved on chemicals, but more expenditure necessary on filters than in II. or IV.	Cost of pumping out as in I., and large cost in chemicals and sludge, less cost in upkeep of beds.	Less cost than I. and II. in pumping out and in sludge removal and chemicals, more work on beds than II., and possibly than I.	More cost in chemicals and sludge, and less on beds than III.	Less cost in chemicals and sludge than IV. Cost for beds same as III., or possibly more.
INITIAL EXPENDITURE	Greater tank area than III. and IV., rather less filter space.	Tank area as in I., but less filter area.	Less tank area than I. and II., more filter area.	Tank area same as III., less filter area than III., more than II.	More tank area than I. to IV., filtering area roughly as in IV.

tical working for primary beds and secondary beds?—That depends entirely on the age of the bed and the dilution of the sewage. In the initial stages of working, long contacts (*e.g.*, 24 hours) have been found advantageous, their effect being to facilitate the formation of a slimy layer of colloidal matter on the medium, in which the real biological action begins. As this layer increases the "absorptive" effect increases also, and less time of contact is required. Moreover, a greater quantity of water is held up in a bed, and the quantity of "draining" increases, till with a bed in long use a very short contact, say a quarter of an hour, is all that is required. With increase in dilution of the tank effluent, due, *e.g.*, to storm water, the period of contact may be reduced to a minimum. In general, after the bed is once "mature" the period of rest is more important than the period of contact, and the total time occupied in 24 hours in filling, standing full, and emptying should not exceed the total of the period of rest. Thus, with frequent fillings the time of contact should be shortened. If the bed takes long to fill, the extra time in filling should be taken from the time of contact. The above all applies to secondary beds, it being understood that as they deal with an effluent containing less impurity they can be worked more rapidly than primary beds.

22799. How should contact beds be filled and emptied?—Contact beds should be filled as far as possible equably from the top, and drawn off also as equably as possible. In this way the maximum of percolating effect is obtained both on filling and emptying. This has the effect of increasing oxidation. It has been found, *e.g.*, that a bed which was yielding well-nitrified filtrates while the surface was rather tight, and when consequently it was nearly covered by the tank effluent when filling the bed, immediately ceased to nitrify after the surface was loosened and the tank effluent filled the bed up from the bottom. Apart from nitrification, however, good percentage purification was still obtained, and the result depends no doubt to some extent on the age of the bed and the consequent proportion of water held up in the pores during the resting period. Slow drawing off is advantageous, as it to a large extent prevents the washing out of suspended matters which are otherwise present in the first flush.

22800. Have you had experience of automatic gear for filling and emptying contact beds?—I have had considerable experience of these devices both on the experimental and working scale at the Davyhulme Works and also at the Withington Works. My experience leads me to think that in large works where skilled supervision must be provided in any case there is no advantage in their use. In small works I think some simple mechanism is useful, chiefly on economic grounds, but it should not be left without some attention, if possible, at least once a day. In small works with the filtering area divided into few units, great fluctuations may occur in the cycle unless some arrangement of dosing tank is provided or storage in the main tank (septic or other). These fluctuations may be harmful by causing the time of filling to be too prolonged, with consequent curtailment of the resting period. The chief difficulty, however, is the constant variation in the water-holding capacity of the beds and in the permeability of the surface, causing pondage and irregular working.

22801. What amount of tank liquor per cubic yard of filtering material can in practice be properly treated in a primary bed, and what amount of liquid from a primary bed can be treated in a secondary bed? Can you deal with larger amounts in times of storm? Is one contact sufficient for certain tank liquors?—It is almost impossible to answer these questions precisely, as the volume which can be dealt with per cubic yard depends upon the character of the sewage and the size of the material. Thus with a bed of cinder screenings (2ft. deep of screenings below 3-16th inch and 6 inches of underdrainage) excellent and sparkling effluents can be obtained with one contact with Manchester settled sewage, but, of course, at a low rate (viz., about 40 gallons per cubic yards). Whether single or double contact should be employed is largely a question of available area and fall. With a sufficient area of fine material one contact will often suffice, but if possible double contact is better as the purification is, as a rule, more thorough when carried out in two stages, and effluents containing a fair amount of suspended matter can be more conveniently treated in primary beds of moderately coarse material. Moreover, renewal charges may be concentrated on to a smaller area. I have come to the general conclusion that in order to obtain a really first-class effluent one cubic yard of material should be provided per person. Then, if the flow per head is less or more, the general result is not affected, except that perhaps with large volumes rather more open material should be provided. This estimate includes storm water. If this number of cubic yards is provided, then the arrangement may depend largely on local circumstances, either single or double contact or percolating filters being employed as may be most economical. The amount of primary effluent which can be treated in a second contact bed depends on the percentage purification effected by the first contact, and this again on the character of the sewage and the size of the material employed for the first contact. Thus at Manchester the first contact effluent is very generally non-putrefactive, a second contact on an area half that of the primary beds will convert it into a good effluent. In Burnley, with a stronger sewage and with contact beds of a larger size of material than in Manchester, the primary effluent is generally far from purified, and a full double contact is desirable. This general rule as to total volume of material needed is, of course, subject to modification in special cases, *e.g.*, a predominance of certain trade effluents might call for special consideration. Again, less margin may be allowed in the area available if competent management can be assured. Further, it is possible to work at a high rate for a short time if double contact is provided at the expense of greater cost in renewal.

22802. At what rate or rates do primary contact beds and secondary contact beds lose their water holding capacity?—I hand in a table which shows the measurements of capacity made in the case of the experimental beds A., B, and C, during the year ending March 1904. The numbers are practically percentages, the original volume of the empty tank being very nearly 10,000 gallons. It should be noted that the measurements were always made to a mark irrespective of the level of the material, so that sometimes pondage occurred on the surface It would be difficult to get out the total number of fillings, but it would not be less in any case than two fillings per day during five years, *i e.*, over 3,500.

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TABLE OF CAPACITIES (Beds A, B, and C.).

Bed B, 5th and 6th Year.			Bed A, 5th Year.			Bed C, 5th Year.		
Date.	Capacity in Gallons.	Drainage Period.	Date.	Capacity in Gallons.	Drainage Period.	Date.	Capacity in Gallons.	Drainage Period.
1903:			1903:			1903:		
30 April -	2,600	7 hours	1 May -	2,350	10 hours	30 April -	2,200	10 hours
3 June -	2,730	6 „	4 June -	2,390	9 „	4 June -	2,510	10 „
25 June -	2,660	6 „	23 June -	2,530	10 „	25 June -	2,450	10 „
23 July -	2,930	6 „	21 July -	2,490	10 „	21 July -	2,580	10 „
1 September	3,040	6 „	8 Sept. -	2,450	10 „	1 September	2,570	10 „
13 October -	2,670	6½ „	1 October -	2,350	6 „	1 October -	2,350	6½ „
30 October -	2,880	6 „	23 October -	2,340	6 „	23 October -	2,470	6 „
7 December -	2,640	6 „	8 December	2,320	6½ „	5 December	2,260	6 „
1904:			1904:			1904:		
14 January -	2,320	10 „	8 January -	2,170	6 „	8 January -	2,180	7 „
5 February -	2,340	9½ „	2 February	2,210	10 „	2 February	2,200	10 „
7 March -	2,370	6 „	4 March -	2,140	10½ „	5 March -	2,060	11 „

I also hand in a table which shows the variation in capacity of some of the primary ½ acre beds. The initial capacity may be taken at 200,000 gallons, or 44 per cent.

CAPACITY MEASUREMENTS—HALF-ACRE BEDS.

Bed No. 1a.				Bed No. 1.				Bed No. 8.				Bed No. 2a.			
Date.	No. of Fillings.	Capacity in Gallons.	Percentage of Empty Tank.	Date.	No. of Fillings.	Capacity in Gallons.	Percentage of Empty Tank.	Date.	No. of Fillings.	Capacity in Gallons.	Percentage of Empty Tank.	Date.	No. of Fillings.	Capacity in Gallons.	Percentage of Empty Tank.
1903:				1903:				1904:				1903:			
27 April	810	121,160	26·7	4 Nov.	872	126,300	27·8	18 Jan.	817	167,340	36·8	23 April	543	136,570	30·0
13 May	824	131,940	29·0	1904:				7 Mar.	903	133,990	29·5	1904:			
22 June	879	132,320	29·1	16 June	1,222	99,220	21·8	27 Sept.	1,257	108,140	23·7	25 Jan.	988	108,140	23·8
21 Aug.	970	127,690	28·1									29 Feb.	1,037	122,030	26·8
26 Oct.	1,070	128,800	28·3									18 Aug.	1,329	108,750	23·9
1904:												1905:			
1 Feb.	1,236	115,910	25·5									8 Feb.	1,685	75,860	17·5
5 Dec.	1,747	96,480	21·0												

Bed No. 2.				Bed No. 3.				Bed No. 5.				Bed No. 9.			
1903:				1903:				1903:				1903:			
16 Nov.	759	137,610	30·3	27 July	484	188,020	41·4	13 Aug.	499	164,000	36·1	8 Dec.	597	203,340	–
1904:				1904:				1904:							
27 June	1,111	128,860	28·0	24 Mar.	912	136,320	30·0	24 Mar.	914	127,330	28·1				

It should be noted that the measurements for beds 1*a*, 2*a*, 1, and 8 do not include the contents of the underdrains, as these beds are, as a rule, owing to special features in their construction, only emptied to the level of the surface of the underdrains, consequently their capacity measurements will tend to be rather below the average of the remainder of the beds, which are completely emptied after each filling. It should be noted that the high measurement recorded for bed No. 8 on January 18th, 1904, was after a prolonged period of rest. The exceptional capacity of bed No. 9 is due to the fact that it is some 6 inches deeper than the majority of beds. In the case of the experimental second contact bed D, loss of capacity did not take place so rapidly as with primary beds, but in its fifth year of working it had sunk to 27 per cent. of the empty tank capacity. The composition of the septic tank effluent dealt with by the beds

Summary of Results Furnished to Royal Commission on Sewage Disposal

(Results in parts per 100,000.)

Period of Four Weeks Ending:	4 Hours' Oxygen Absorption.												Ammoniacal Nitrogen.											
	Raw Sewage.			Open Septic Tank Effluent.			Primary Filtrate.			Storm Beds Filtrate.			Raw Sewage.			Open Septic Tank Effluent.			Primary Filtrate.			Storm Beds Filtrate.		
	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best	Average.	Worst.	Best.	Average.
22 April, 1903	15·13	7·36	10·11	10·97	6·00	8·10	4·34	·74	2·31	2·00	·51	1·16	3·02	1·09	2·19	3·88	1·76	2·48	3·23	·94	1·65	1·33	·35	·96
20 May, 1903	13·71	6·87	10·26	10·91	3·54	7·37	3·91	·74	2·40	2·06	·60	1·20	2·96	1·06	2·13	3·58	1·00	2·32	2·58	·53	1·51	1·47	·41	·90
17 June, 1903	14·27	5·61	11·03	10·69	4·34	8·46	4·14	1·20	3·11	2·06	·66	1·30	3·47	1·00	2·81	4·70	2·29	3·54	3·29	1·23	2·03	1·76	·70	1·08
15 July, 1903	15·14	7·81	11·81	12·51	6·11	8·44	4·83	1·00	2·78	2·51	·89	1·44	3·55	1·21	2·54	4·23	1·88	3·09	3·53	·88	1·80	1·47	·29	1·07
12 August, 1903	13·56	4·61	10·35	8·91	4·57	7·40	3·34	·74	3·34	2·14	·50	1·34	2·97	1·33	2·34	3·52	1·64	2·61	2·47	1·06	1·65	1·52	·35	1·00
9 September, 1903	14·84	5·53	8·39	8·46	4·40	6·30	3·03	·80	1·84	2·20	·60	·98	3·20	1·03	2·03	3·23	1·12	2·20	2·41	·53	1·26	1·29	·29	·76
7 October, 1903	17·31	6·73	10·34	10·11	5·77	8·00	5·23	·89	2·54	2·37	·74	1·57	3·21	1·20	2·41	4·23	1·70	3·05	3·29	·41	1·76	1·43	·35	1·01
4 November, 1903	12·40	5·20	7·66	9·60	4·34	6·10	2·54	1·44	1·87	2·62	·51	1·17	3·41	·70	1·67	3·65	·82	1·74	1·42	·69	1·12	2·06	·18	·63
2 December, 1903	14·51	6·11	10·20	12·63	6·00	8·32	5·20	1·14	2·59	4·06	·76	1·73	2·65	1·17	2·03	3·35	1·53	2·45	2·41	·88	1·54	2·17	·29	1·08
30 December, 1903	16·40	7·89	12·11	14·40	6·86	9·83	5·37	1·54	3 19	4·11	·74	2·47	4·47	1·78	2·66	4·82	1·47	3·32	3·00	·82	1·90	2·18	·70	1·46
27 January, 1904	15·37	8·11	11·43	12·51	6·97	9·91	6·29	1·63	3·29	4·31	1·09	2·53	4·53	·76	2·50	4·53	·93	2·75	3·18	·65	1·72	2·47	·41	1·39
24 February, 1904	14·74	6·91	10·80	10·46	5·71	8·29	4·94	1·37	2·84	3·23	·86	2·04	2·94	1·18	1·89	3·17	1·05	1·96	2·23	·70	1·43	1·76	·47	1·07
30 March, 1904 (5 weeks)	14·91	8·57	11·94	12·51	7·89	10·09	5·14	1·54	3·31	4·14	·86	2·39	3·12	·94	2·35	3·94	1·29	2·72	2·11	·82	1·68	2·27	·59	1·37

Period of Four Weeks Ending:	Albuminoid Nitrogen.												Nitric Nitrogen.						Percentage of Dissolved Oxygen taken up in 48 hours at 80° Fahrenheit.						Tank Liquor Filtered gallons per cubic yard per day.	
	Raw Sewage.			Open Septic Tank Effluent.			Primary Filtrate.			Storm Beds Filtrate.			Primary Filtrate.			Storm Beds Filtrate.			Primary Filtrate.			Storm Beds Filtrate.			Primary Filtrate.	Storm Beds Filtrate.
	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.	Worst.	Best.	Average.		
22 April, 1903	·85	·29	·51	·49	·28	·37	·22	·08	·16	·15	·03	·09	·01	·00	·06	·41	1·29	·86	98	28	44	—	—	28	55	65
20 May, 1903	·74	·29	·48	·51	·16	·35	·27	·07	·17	·16	·05	·10	·23	·85	·19	·33	1·45	·74	69	22	38	33	15	22	65	60
17 June, 1903	·96	·50	·66	·53	·29	·42	·28	·14	·20	·16	·07	·11	·01	·42	·09	·54	1·47	·95	65	34	50	41	14	24	68	59
15 July, 1903	·92	·34	·59	·50	·26	·38	·28	·07	·17	·15	·05	·11	·01	·98	·22	·26	1·15	·63	66	33	48	47	16	29	57	77
12 August, 1903	·69	·39	·52	·43	·27	·35	·25	·09	·16	·15	·05	·11	·02	·82	·27	·16	1·12	·52	64	31	43	37	13	24	56	83
9 September, 1903	·72	·15	·47	·43	·25	·34	·23	·06	·13	·14	·05	·09	·02	·77	·29	·16	·96	·54	—	—	—	—	—	—	84	61
7 October, 1903	·90	·34	·59	·53	·26	·40	·26	·07	·16	·17	·05	·12	Nil	·87	·30	·01	3·52	·73	—	—	—	—	—	—	83	96
4 November, 1903	·82	·20	·39	·53	·19	·27	·12	·07	·10	·18	·01	·06	·17	·60	·34	Nil	·92	·47	26	16	22	28	6	18	104	109
2 December, 1903	·78	·18	·48	·45	·20	·35	·20	·05	·13	·25	·02	·10	·01	·81	·30	·07	·92	·48	52	15	37	43	14	28	82	85
30 December, 1903	·98	·30	·55	·69	·19	·45	·30	·06	·18	·25	·05	·14	·02	1·08	·41	·19	1·29	·62	—	—	—	—	—	—	72	74
27 January, 1904	·87	·26	·55	·63	·19	·45	·29	·06	·16	·29	·03	·13	·03	·92	·40	·07	1·01	·60	—	—	—	—	—	—	86	78
24 February, 1904	69	·13	·43	·52	·13	·31	·26	·03	·13	·19	·02	·09	·06	1·01	·46	·44	1·17	·63	—	—	—	—	—	—	96	90
30 March, 1904 (5 weeks)	·70	·26	·49	·60	·19	·40	·23	·05	·15	·23	·03	·12	·02	·80	·38	·23	1·01	·52	64	31	48	57	30	42	81	75

referred to is given in the following table, the average suspended matters present amounting to a total of 10·0 parts per 100,000, of which 5·7 were mineral. (*See* Table headed "Summary of Results furnished to Royal Commission on Sewage Disposal.")

22303. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed or to the fineness or coarseness of the material of the bed, or on what does it depend?—The causes of loss of capacity are set out in the extract which I hand in. In regard to paragraph (*b*) it may be added that the colloidal matters in the sewage are deposited on the medium, and constitute part of the jelly-like material. Further, a residual humus is formed in oxidation of the organic matter present, which either tends to fill up the bed or to come away in the effluent.

CAUSES OF LOSS OF CAPACITY OF CONTACT BEDS.

From the experience gained with beds A, B, C, and D, and also with the other experimental beds reported upon, it has been concluded that the chief causes of loss of capacity are the following:—

(*a*) Settling together of the material.

(*b*) Growth of organisms.

(*c*) Impaired drainage.

(*d*) Insoluble matter entering bed.

(*e*) Breaking down of material.

(*a*) Settling together of Material.—This must always occur, and largely accounts for the initial rapid decrease in capacity. It may be well, at the outset, to place the material in the bed to a slightly greater depth than that actually required, so as to allow for this settlement.

(*b*) Growth of Organisms.—This is at once the cause of increased efficiency in the bed, and of loss of capacity. On examining the material of a contact bed in active condition, every piece is seen to be coated over with a slimy growth. If this is removed it soon dries to a stiff jelly, which can be cut with a knife. Under the microscope masses of bacteria and zoogloea will be found to be present. If placed in a tube containing air and connected with a manometer the jelly will rapidly absorb all the oxygen and produce carbon dioxide.

This action will sometimes produce a vacuum of several inches of mercury. There is little need, therefore, to force air into a bed, as the natural interchange of gases which takes place is sufficient for adequate aeration. As a matter of fact, there is always a large amount of oxygen to be found at the bottom of a bed in good condition. The behaviour of the bacterial jelly appears to afford the clue to the successful working of bacteria beds. By working them at a high speed —*i.e.*, filling them frequently in the day, without long periods of rest—the effluent may remain good, but the bacterial growth so rapidly increases that the bed becomes too spongy, and will not allow the water to drain away. Here, too, is the explanation of the fact that, within limits, decrease of capacity is accompanied by increase of efficiency.

This decrease of capacity may, however, become so great as to outweigh the advantage of increased efficiency. A long period, say one or two weeks' rest, must then be given to the bed.

The superfluous bacterial growths will during this time be rapidly consumed, and the capacity of the bed will greatly increase. These rests should not exceed a fortnight at most, as the bed then tends to dry up and the activity of the organisms diminishes.

It is therefore important that the decrease of capacity should not be allowed to become excessive before resting, or it may not be possible to completely recover the loss during the time of rest.

In the case of the beds A, B, and C, before the best conditions of working had been ascertained, the capacity had been allowed to decrease to an undesirable extent.

(c) Impaired Drainage.—Defective drainage decreases the actual water capacity of the beds and prevents thorough aeration, and every means should be taken, therefore, to make it as perfect as possible.

(d) Insoluble matter entering bed.—The effect of insoluble matter in decreasing capacity depends on its nature. If sandy in character its effect will be small, as the sand itself has a water-holding capacity.

In Manchester the chief insoluble matters entering the bed are finely-divided clay (especially in wet weather) and compounds of iron. Most of the iron in the septic tank effluent is in suspension as sulphide. This can largely be retained on the surface of the bed. The small amount of iron which is deposited from solution can affect the capacity only very gradually. As a matter of fact, most of the insoluble matter passing on to the beds appears to be in the top six inches, and if the cinders below this are left undisturbed a fairly sharp line can be distinguished between the surface layer and the cinders. The fact that no permanent loss of capacity has occurred over 15 months shows that most of the insoluble matter must have remained on the surface of the bed, and such as has entered must itself possess a water capacity.

Evidently, then, it is of importance to retain insoluble matter as far as possible on the surface. This may be done by making the upper layer of rather finer material than the body of the bed. Experiments are in progress to determine whether in course of time this upper layer can be used after removal for growing vegetables, as it has been found to contain large quantities of nitrates and some phosphoric acid.

(e) Breaking Down of Material.—Little, if any, evidence of this is present in the beds under discussion. Its occurrence would be a more serious cause of loss of capacity than any of the foregoing, and should be avoided by using only hard refractory material.

22304. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost?—Yes, easily, by means of an elevator working in a sump through which effluent runs and into which the clogged material is tipped. The water and material are carried by the elevator on to a rotary screen. This is done at Burnley at 1s. per cubic yard, exclusive of capital cost of plant.

22305. How can the capacity of contact beds be best maintained?—The method of procedure which experience leads us to recommend for the successful working of contact beds is:—

(i.) The bed should be worked very slowly at first in order to allow it to settle down and the bacterial growths to form. In this way there will be less danger of suspended matter finding its way into the body of the bed while the material is still loose and open.

(ii.) The burden should not be increased till analysis reveals the presence of surplus oxygen, either dissolved or in the form of nitrates in the effluent.

(iii.) Analyses of the air in the bed may usefully be made from time to time during resting periods.

(iv.) The variations in capacity should be carefully recorded. If the capacity is found to be rapidly decreasing a period of rest should be allowed.

(v.) Long periods of rest should be avoided during winter, as when deprived of the heat of the sewage the activity of the organisms decreases. If necessary, the burden on the bed should then be decreased by reducing the number of fillings per day rather than by giving a long rest at one time.

(vi.) The insoluble suspended matter should be retained on the surface by covering, at any rate, a portion of the latter with a layer of finer material not more than 3 in. in depth. The suspended matter thus arrested should not be raked into the bed, but when its amount becomes excessive it should be scraped off. This should be done, if possible, in dry, warm weather, after the bed has rested some days. By placing the inlet and outlet penstocks as close together as possible the suspended matter will tend to concentrate in their vicinity, and its removal will be facilitated.

22306. What are the average analyses of your single contact effluent and your double contact effluent?—The analyses are as follow:—

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EXPERIMENTAL FILTRATION. (May 1900—March 1901.)

Average Results (parts per 100,000.)

4 Hours Oxygen absorption.		Ammoniacal Nitrogen.		Albuminoid Nitrogen.		Chlorine.		Nitrous Nitrogen.		Nitric Nitrogen.		Incubator Test. 3 minutes before.		Incubator Test. 3 minutes after.		Putrescence.	
P.*	S.*	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.
2·37	·77	·846	·270	·152	·063	15·7	15·3	·035	·023	·646	1·17	1·20	·336	1·09	·25	$\frac{43\frac{1}{2}}{218}$	$\frac{0}{351}$

*P = Primary Bed. *S = Secondary Bed.

FILTRATION ON THE LARGE SCALE (PRIMARY BEDS).

Average Results, year ending March 29th, 1905.

2·99	1·65	·15	19·3	·03	·34	1·60	1·66	$\frac{177\frac{1}{2}}{462}$

22807. What number of gallons of liquid are treated daily per cubic yard of filter material in your first bed, and what number of gallons are treated daily per cubic yard of filtering material in the two filters?—About 90 gallons per cubic yard in the first bed and about 65 gallons per cubic yard in the two beds.

22808. Do you find any chemical poisons in the final effluent?—No.

22809. What is the average amount of suspended matter in the primary bed effluent and the secondary bed effluent? Does most of this suspended matter come out with the first flush or not?—The average amount in the primary bed effluent is about four parts per 100,000. There is practically none in the secondary bed effluent if the bed is not overworked. Most of the suspended matter comes out with the first flush.

22810. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed is different from the organic matter of the suspended solids going on to that bed?—It is more granular and less colloidal. It contains much organic life. Further investigation is needed before a full statement on this point could be made.

22811. Is the first flush of effluent from either set of beds ever putrescible?—Yes.

22812. Do you find that by increasing the number of fillings in storm times or other times the amount of suspended solids is increased?—No, except through clay passing through the filters in the early stages of a storm.

22813. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency, and, if so, do you think there are advantages in so working them?—Yes, but short contacts are better. Streaming requires less attention and is useful therefore in an emergency.

22814. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per 24 hours in ordinary times and in storm times? Please state whether you have single or double contact, and what is the depth of your beds?—The engineer will give evidence as to the cost. The amount treated is about 400,000 gallons per acre in ordinary times, and as much as 1,000,000 per acre on a very wet day. We have single contact, and the depth of the beds is 3ft. 4in.

22815. Have you made any experiments which throw light upon the action of contact beds when full and when resting?—Yes; very briefly the results are: (1) Long contacts with new beds show that much impurity may be removed simply by physical effect of contact. (2) Absorption of oxygen and proportion of CO_2 by jelly-like humus from beds shows active oxidation during rest. (3) Washing out of bed with tap water during rests shows that nitrates are formed during this period and partly used up in oxidising organic matter during the standing full period.

22816. Have you made a study of the conditions of aeration of contact beds, and, if so, with what results?—Yes, I have never found any serious deficiency of oxygen except when the bed was obviously overworked. In that case the bed recovered rapidly on resting, as will be seen from the table which I hand in.

TABLE.

Sample of Air from Bed D (Experimental Secondary Bed).

In each case the air was drawn from one foot below the surface, *i.e.*, halfway down the filter.

No. of days resting.	Percentage Composition. (Volume.) CO_2	Oxygen.	Remarks.
6 days -	2·2 per cent.	8·9 per cent.	Owing to experimental work before commencement of rest, the bed was in bad condition, thoroughly sodden.
10 „ -	1·2 per cent.	19·3 per cent.	
17 „ -	0·9 per cent.	20·5 per cent.	

22817. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—There has been no nuisance, and no complaints have been made.

22818. As regards continuous or percolating filters, what do you find are the best filtering materials?—I may refer to what I said in reply to a similar question in connection with contact beds (*see* 22794). It is of vital importance in a continuous filter that there should be no breaking down of the material with consequent formation of inequalities in the distribution; for the same reason all fine dust must be carefully removed from the material, therefore while the same materials may be used for their construction, as are used for contact beds, great care must be exercised in their selection.

22819. What size should the filtering material be, and what depth?—The following experiments show that with the same liquid the purification increases directly with the fineness of the material.

PERCOLATING FILTERS dealing with Manchester Open Septic Tank Effluent.

Analytical Results.

Showing effect of size of material on filtrate obtained:

1. Material anything above 3-16 in. Very little coarse.
2. Material passed through 2 in. mesh and rejected ½ in. mesh.
3. Material larger than 2 in.

	1.	2.	3.
4 Hours' Test	2·70	3·80	4·63
Ammoniacal Nitrogen	1·69	2·41	2·98
Albuminoid Nitrogen	·15	·21	·22
Nitrous Nitrogen	·06	·05	·02
Nitric Nitrogen	·83	·18	·07
3 Minutes' Oxygen Test	1·36	2·36	2·53
3 Minutes' Oxygen Test (after incubation).	1·19	2·86	3·29
Putrescibility	2½/73	26½/40	35/38
Chlorine	—	—	18·6
Average amount dealt with per cubic yard per day.	130 gallons.	94 gallons.	75 gallons.
Depth of filter	3 feet.	3 feet.	6 feet.

22820. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?—In certain cases, if very efficient screening is resorted to, tank treatment may be successfully dispensed with before the liquid is applied to the percolating filter, but correspondingly greater provision will have to be made at the outlet of the filter. In this case, moreover, the filter must be constructed of coarse material.

22821. Can you say whether the material is better disposed in the form of two beds, to be fed in succession with the same liquid, or in one deep bed?—That point has not come within my direct experience.

22822. How should percolating filters be fed?—I prefer a "controlled" filter of the type of those at Friern Barnet and Flixton, *i.e.*, with a fine top layer. This form of filter has shown itself capable of working successfully for many years. It cannot be easily overdosed, and has no mechanical parts to get out of order, though the maintenance charges may be rather higher. I have found by experiments that precisely the same results can be obtained from two filters, identical in all respects, except that one was fed by an expensive distributor and the other by a fine top layer.

22823. Should the feed be intermittent or continuous?—I have found that a continuous flow at a moderate rate, with occasional intervals of rest, gives a better result than intermittent flushes; where this condition cannot be secured any intermittent dose should be as small as possible.

22824. What is the best form of distribution? What, in your opinion, are the conditions which have to be fulfilled by a perfect distributor, having regard not merely to the distribution of the liquid itself, but also to the purification of the liquid and the life of the bed?—A good distributor must fulfil the following conditions:—(1) It must distribute the liquid equally on all parts of the bed; (2) it must not be subject to stoppage by friction, wind, blockage of holes, or frost; (3) it must never discharge more than the bed will purify; (4) its cost must not be in excess of the work done.

22825. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—So far as my rather limited experience goes I am inclined to think that the amount passing on to the filter can be increased in time of storm without prejudicial effect.

22826. Is there any practical advantage in artificially heating the liquid which is being treated upon percolating filters?—I have no direct experience on that point.

22827. Have you had any experience to show whether open sides are an advantage to a percolating filter?—Our experience goes to show that aeration takes place from the top and not from the sides of a percolating filter, as it has been found that a filter which was partially enclosed at first gave no different results when the sides were left open.

22828. Have you made any study of the conditions of aeration of percolating filters?—The following typical analyses, made under strictly comparative conditions, show that there is a slightly greater percentage of oxygen in a continuous filter than in a contact bed, but the difference is not considerable:—

Examination of air in Experimental Box Filters.

(a) Immediately before working:

	Continuous Filter.	Contact Bed.
Oxygen	21·0 per cent.	20·6 per cent.
CO_2	1·2 „	0·6 „

(b) Continuous filter, during working of filter:

Oxygen - - - - - 19 per cent.

CO_2 - - - - - 0·5 „

(3) Contact bed, two hours after discharge:

Oxygen - - - - - 18·7 per cent.

CO_2 - - - - - 1·0 „

22829. What do you consider is the most convenient superficial area for a percolating filter?—(*see* 23020).

22830. Do you think it desirable that the bottom of a percolating filter be raised from the ground?—Only so far as is necessary to ensure a perfectly free clearance for water and air at the bottom of the filter.

22831. Do percolating beds, in your experience, choke?—I have not noticed this in my own experiments, but have seen cases where choking has taken place.

22832. Of what nature are the suspended solids in the filter effluent? How much is organic matter, and are they putrescible apart from the liquid portion of the effluent?—The following analysis of the suspended solids in the effluent of a continuous filter in Manchester was made by Mr. Raymond Ross, of Burnley. It is putrescible apart from the liquid portion of the effluent.

Analysis of Suspended Solids from Continuous Filter, Manchester. (R. Ross.)

Moisture	82·29
Mineral	9·37
Organic	8·34
Dried residue	—
Nitrogen	2·79
Carbon	23·04
Hydrogen	3·44

Mineral matter mainly oxide of iron.

22833. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a percolating filter is different from the organic matter of the suspended solids going to that filter?—Extended investigation is necessary to properly answer this question.

22834. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter; and to what minimum figure do you think such settlement or other final treatment can be carried as a *practical* measure?—Settlement appears to me, from the character and amount of the suspended matter

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issuing from the open continuous filter in Manchester, to be inadequate, and some form of straining filter is necessary. If this reduces the final suspended matter (*i.e.*, the total amount obtained on standing) to, say, an average of 2 grains and a maximum of 3, this should fulfil all practical requirements.

22835. Do you find that the suspended solids in your filter effluent vary very much in amount from time to time; and, if so, can you explain the causes of such variation?—Yes, but have not followed this question very closely.

22836. What was the cost of your percolating bed installation per acre, and how much liquid do you treat per acre, per 24 hours, at ordinary times and in storm times?—The experimental filter in Manchester was very costly, but it would not be fair to give the figures as a basis of comparison.

22837. Have you made any experiments which throw light on the action of percolating filters, with regard to the oxidation of the ammoniacal and organic matter in solution and of the organic matter in suspension? Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter, or that they are first absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one?—As regards the ammoniacal and organic matter in solution, much depends on the size of the material and consequent proportion of liquid held up in the interstices. Experiments with fluorescein show that with an open filter a certain proportion of the *liquid* comes through very rapidly; a remaining portion takes a much longer time. Laboratory experiments have shown that *ammonium salts* are absorbed by washed and sterile clinker, and I have very little doubt that their passage through a percolating filter is in reality very slow, a constant sequence of physical and chemical changes taking place depending on the size and character of the material, the extent to which it is coated with gelatinous matter, the variations in the strength of the effluent applied, and in the rate of its application. In general the action of a percolating filter tends to the formation of nitrates, by oxidation of ammonia, rather than to the breaking down of complex organic compounds in solution. The organic matter in suspension is certainly changed in passing through a percolating filter, but further study is necessary before speaking in detail on this point.

22838. Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter?—I have noted that unless the effluent is kept constantly moving by the distributor used for feeding the filter, it will freeze in cold weather.

22839. Have you found any trouble from vegetable growths in percolating filters? If so, have you been able to form any opinion as to the causes of these growths, and as to the way in which the growths can be prevented?—With an experimental filter of fine material some amount of growth formed on the surface after long use, and in an open filter slimy growths certainly tended to form here and there on the surface. This appears to me to be due to the fact that large quantities of unpurified effluent are applied in one place, and consequently fungoid growths of the usual character follow. The remedy would appear to consist in applying less per square yard or in carrying preliminary treatment further.

22840. Do you find any nuisance from the treatment of sewage on percolating filters? Have any complaints been made?—With the experimental filter in Manchester it cannot be said that any appreciable nuisance arose. An extraordinary development of insect life, flies, spiders, etc., was, however, remarked, though the flies did not appear to get away from the filter. In more than one other installation I have seen, however, I am bound to say that the clouds of peculiar large-winged flies were extremely objectionable. I have never noticed any appreciable smell from percolating filters.

22841. Would you kindly compare the cost (initial expenditure and annual cost of upkeep and working) and relative advantages of percolating filters and contact beds? Do you consider that one form is best for some kinds of sewage, and the other form for other kinds of sewage?—The following extracts from a paper read by me before the Congress of the Royal Sanitary Institute in Glasgow in July, 1904, will best answer this question:—

"Through the kindness of some of my friends I am able to give a preliminary table of data which, though not complete in all respects, will serve as an illustration of my argument, and as a basis for what I hope may be a useful discussion. For these data I have to thank Mr. Newton, of Accrington; Messrs. Pickles and Ross, of Burnley; Mr. Watson, of Birmingham; and Mr. Valentine, of Oldham.

"The following are some of the conclusions which appear to me to be justified by the table:—

"1. That it is not possible to say on merely general grounds that one process is to be preferred to another, equally good results being obtained by a number of methods if carried far enough.

"2. That percolating filters are more expensive than contact beds in first cost.

"3. That whether they justify this extra first cost depends on local conditions.

"4. That where pumping would be necessary in order to operate sprinkling filters, as at Burnley, Manchester, and Oldham, then contact beds are cheaper.

"5. That where a sufficient area of contact beds can be obtained at a low cost of construction, as at Oldham, they are cheaper under all circumstances.

"6. That, for purposes of comparison, costs should be calculated on the dry weather flow.

"7. That, other things being equal, a small flow per head conduces to economical treatment."

COMPARATIVE DATA RE FILTRATION OF TANK EFFLUENT.

	MANCHESTER.		ACCRINGTON.	BURNLEY.	OLDHAM.	BIRMINGHAM.
Population	574,800		50,000	98,400	154,000	750,000
Character of sewage (purely domestic or manufacturing).	Manufacturing.		Domestic and Trade	Principally domestic.	Mainly domestic (great proportion of slop water-closets).	Domestic and manufacturing.
Dry weather flow per head of population	40		24¼	25	17¾	30
Average flow per head of population	60		35¾	—	1902. 28·6 — 1903. 40·2	40 (approx.)
Tank treatment — Chemical	½-acre beds. —	Storm beds. Chemical.	—	—	—	—
Tank treatment — Sedimentation	—	Sedimentation.	—	—	Sedimentation.	Sedimentation.
Tank treatment — Septic	Open septic.	—	Two series of three open septic tanks.	Open septic tanks (with very large detritus tanks).	About ⅛ of flow through experimental closed tank.	Septic.
Filtration system — Intermittent	Intermittent.	Intermittent.	—	Intermittent.	Intermittent.	[ment. Mainly land treat-
Filtration system — Continuous	—	Streaming.	Continuous.	—	Occasionally streamed in time of storm.	Continuous.
Size of filtering medium	3/16 in. and upwards	Ungraded clinker, free from dust. Large clinker round drains.	2 to 3 in.	Primary beds ¾ in. and upwards. Secondary beds ⅛ in. to ¾ in. (The above are both washed and screened.)	Ungraded clinker, &c., free from dust. Large clinker round drains.	2½ in., 1½ in., 1 in., and ½ in.
Percentage purification on tank effluent—					Jan.–May. 1903. 1904.	
4 hours' oxygen test	68 per cent.	75 per cent.	77 per cent.	87 per cent.	73·7 75·4	—
Albuminoid	59 per cent.	72 per cent.	75 per cent.	87 per cent.	57·9 56·7	—
Percentage of free ammonia in tank effluent appearing as nitrite and nitrate in filtrate.	17 per cent.	36 per cent.	60 per cent.	29 per cent.	1903. 12·7 1904. 12·2	—
Average quantity dealt with per acre yard per day during one year, including all rests.	431,000	377,000	645,300	169,400 by double contact.	1903. 286,000 1904. 363,426 exclusive of storm-water.	—
Construction cost per acre yard	£2,376	£1,765	£3,630	£1,300.	£800 (approx.)	£3,000.
Working cost of beds per million gallons filtered (apart from renewal of material and miscellaneous expenses of works management), average per annum.	3s. 8d.		1s. 11d.	7s. 6d.*	1903. 6s. 3·3d. 1904. 4s. 8·3d.	£20 per ¼ acre bed per annum.
Renewal cost per acre yard per annum, average	£50 (estimated from Burnley results).	£40	Nil.	—	£41 7s.	Nil.
Renewal cost per million gallons filtered	6s. 6d.	5s. 9d.	Nil.	16s.	7s. 11d.	Nil.
Cost of sludge disposal per million gallons of sewage	10s. 3d.	—	2s. 8d.*	5s. 8d.	14s. 1d.	3d. per ton.
Total cost of treatment per million gallons—					1902. 1903.	
Dry weather flow	£1 13s. 5d.	—	£3 7s. 0d.†	£3 7s. 6·7d.†	— —	—
Total flow	£1 2s. 3·9d.	—	£2 4s. 8d.	—	£1 14s. 8d. £1 4s. 8d.†	
Cost per head of population per annum	5·85d.	—	7·12d.	7·39d.	2·69d. 4·33d.	—
Remarks	The total cost of treatment does not include renewal costs, which have not yet been incurred. On the other hand, the cost of sludge disposal will probably be reduced in the future.		* The sludge is lagooned and sold; the cost given is the net cost. † The total cost is largely due to pumping, which it is intended shortly to dispense with.	*Cost of working beds, sampling, weeding, and cleaning and levelling distributing troughs. †Total expenditure £2,866 8s. Receipts from sludge manure and crops £400 8s. Net cost £2,466.	†Abnormal rainfall of 1903 reduces cost per million gallons.	—

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It is fair to say that in the discussion which followed the reading of the paper it was contended that continuous filters could be put up much more cheaply than in the cases quoted in the table. This may be so, but in order to form a judgment of their economy the amount treated per acre yard would have to be known.

22842. Do you find the chance of nuisance is any greater with one form of filter than with another?—I have referred to the development of insect life in connection with percolating filters (*see* 22840). I have never come across a case of nuisance from contact beds nor from continuous filters worked as "controlled" filters.

22843. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor or tank liquors could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds? If so, would you kindly state the results, at the same time telling us in precise terms what was the composition of your tank liquor or tank liquors, and what you are considering to be a satisfactory effluent?—The following results, obtained with small experimental filters 3ft. deep and 2ft. square, worked under absolutely comparable conditions, may give some information in regard to this question :—

ANALYTICAL RESULTS.

A. Continuous Filter. B. Contact Bed.

Amount of Septic Tank Effluent dealt with being the same in each case, being gradually increased up to about 100 gallons per cube yard.

Date.	4 Hours' Oxygen Test.			Ammoniacal Nitrogen.			Albuminoid Nitrogen.			Nitrous Nitrogen.		Nitric Nitrogen.		Incubation (3 Minutes' Oxygen Test).						
Month, 1904–5.	Tank Effluent.	A.	B.	Tank Effluent.	A.	B.	Tank Effluent.	A.	B.	A.	B.	A.	B.	Tank. Effluent.	A. Before.	A. After.	A. Putrescibility.	B. Before.	B. After.	B. Putrescibility.
April	15·66	2·01	1·94	2·84	1·88	1·60	·65	·10	·09	·07	·04	1·03	·88	8·14	1·01	·77	0/17	1·04	·79	0/17
May	15·73	2·16	2·21	3·14	2·25	1·89	·69	·12	·10	·07	·06	1·19	·98	9·10	1·16	·86	0/10	1·21	·94	0/10
June	8·93	1·69	2·34	3·46	1·65	1·67	·35	·12	·14	·06	·05	1·23	·79	4·56	·74	·63	½/7	1·04	·84	0/7
July	11·73	1·40	1·64	2·99	1·21	1·35	·41	.10	·10	·07	·05	·83	·61	6·19	·69	·61	0/8	·84	·67	0/8
August	17·80	1·53	1·67	3·44	1·45	1·57	·76	·09	·11	·08	·05	·87	·56	7·69	·74	·69	0/6	·86	·80	0/6
September	21·30	2·43	2·77	3·36	1·55	1·59	·85	·15	·15	·07	·05	·92	·67	8·56	1·21	·93	0/5	1·49	1·39	2/5
October	12·07	3·13	3·29	2·59	1·81	1·81	·53	·17	·19	·08	·04	·68	·48	6·26	1·61	·90	0/4	1·86	2·11	2/4
November	9·86	3·40	3·69	2·41	1·93	1·87	·38	·20	·19	·04	·04	·59	·47	5·23	1·96	1·91	1/4	2·20	2·29	3/4
December	9·97	2·13	2·99	2·39	1·32	1·23	·40	·14	·17	·03	·04	1·06	·72	4·37	1·03	·77	0/2	1·57	1·39	0/2
January	9·64	4·56	3·44	2·47	1·92	1·41	·39	·15	·15	·03	·06	·54	·26	4·90	1·70	1·41	0/3	1·94	1·90	½/3
February	11·20	5·46	4·01	2·76	2·15	1·94	·48	·28	·20	·06	·04	·28	·19	5·77	3·09	3·56	1/2	2·23	2·61	1/2
March	7·17	2·50	2·73	1·94	1·22	1·02	·29	·12	·13	·06	·06	·83	·53	3·63	1·40	1·13	0/5	1·51	1·49	1/5
Average	12·59	2·70	2·71	2·81	1·69	1·57	·52	·15	·15	·06	·05	·83	·60	6·20	1·36	1·19	2½/73	1·49	1·43	9½/73

Note.—The filters were constructed of the similar-sized material, *i.e.*, ordinary cinders screened over a 3/16″ mesh, very small proportion of coarse material.

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22844. Could you express an opinion as to how the number of gallons would vary with variations in the strength of your tank liquor, and on what figure or figures you would rely for defining the "strength" of your tank liquor?—The amount treated on our contact beds will vary from 350,000 gallons in dry weather to as much as 1,000,000 gallons per acre per day in wet weather. The chlorine number is generally taken as an index of the strength of the sewage. As a matter of practice, however, it is not always possible to adjust the rate of treatment exactly to the strength of the sewage, as the volume is often largest while the sewage is still strong. As a practical measure to prevent as far as possible the pollution of the stream receiving the effluent, it is best to treat as much as possible of the foul first flush, even if some of the latter part of the rainfall passes away unfiltered. In this way the average effluent entering the stream will be better, and the beds will not be taxed on the average out of proportion to the flow, experiment having shown that a number of contacts can be given in quick succession provided they are succeeded by adequate rest.

22845. Have you had any experience of storm-water filters?—The results of my experience with the storm-water filters at Manchester are summarised in the following paragraphs, taken from the annual reports of the Manchester Rivers Committee:—

THE STORM BEDS.

"The original intention was to put only the weak night sewage on to the storm beds in dry weather, but in order to produce as good an average effluent as possible pending the completion of the works, the effluent from the chemical treatment of a part of the day sewage has been put upon them. This should be borne in mind in judging the average quantities dealt with by these beds, as they were constructed with the view of dealing at a rapid rate with dilute sewage only.

"As regards analytical work, separate analysis is made each day of the average tank effluent passing to each area, and of the discharge, individual beds being sampled separately from time to time, as appears desirable.

"All these arrangements are subject to modification in time of storm. The procedure depends in such a case on the dilution of the sewage, the number of fillings being increased and the water allowed to pond up to the level of the bellmouth, or even to flow continuously through the bellmouths for limited periods. The average results obtained when the beds were working in this manner are given in the Table.

"In time of storm the number of fillings on the half-acre beds is also increased, and in this connection special attention is directed to the Table where details are given of the results of dealing with storm water on a number of specified dates.

"The composition of the total effluent obtained on these occasions is arrived at by averaging the analytical results from the various effluents leaving the works in proportion to the volume of each.

"These results show that it is possible to deal satisfactorily with very large volumes of storm water, the returns for October 28th, November 2nd, November 28th, and February 4th being especially noteworthy.

"In some cases—*e.g.*, October 28th, 1903—in order to make the best use of the acreage available, the tank effluent was allowed to pass away unfiltered at its period of greatest dilution, only the stronger effluent being put upon the beds. By this means, although the rate of filtration is not very excessive, the average result obtained is more satisfactory than if the beds had been used during the period of greatest dilution.

"The results given in the Tables show that the purification effected by these beds has been highly satisfactory. Owing, doubtless, to the fine material of which they are composed, and the fact that in dry weather they are only filled once a day, the nitrification in the matured beds has been exceptionally high. The beds which were started in the summer took less time to mature than those which were started in the winter months, but all are now giving satisfactory results. This large production of nitrates in dry weather enables the beds to be successfully used at a more rapid rate, or even as streaming filters in time of storm, and entirely bears out the intention with which the beds were constructed.

"The control of the whole of both areas of storm beds has been in the hands of two men, their shifts overlapping two or more hours in the middle of the day. Since the whole area has been in operation one or two men have been pretty generally employed in removing the grease, which still tends to collect at the corner of the beds, though to a less extent than formerly; these men also attend to the light harrowing of the beds, the harrow being drawn by a donkey. The frequency of this latter operation depends upon the weather, but it is seldom required more than once a month, even on the oldest beds. The largest bed can be harrowed in one shift, so that it is not a very costly operation.

"The scraping operations mentioned in the annual report for 1902-3 were continued during the months of May and June, 1903, the whole of the easterly area receiving attention; the amount of labour, however, varying considerably on different beds, the extra labour in many cases being due to relevelling the surface. The cost varied from about 30s. to £12 per bed, all of which is included in the filtration costs.

"It may be of interest to note that a sample of the scraped-off material from a specially bad part of the surface was found, on drying and extracting with ether, to yield ·37 per cent. of greasy extract. Dr. Carl Schreiber, in his investigation of the grease on the Berlin land filters, concludes that ·10 per cent. is sufficient to render sand impervious to water.

"The scraped-off material was burnt in heaps with the addition of a little coal. After being once started, the heap gradually burnt through with practically no further attention, owing chiefly to the particles of coke and coal intermixed with the original clinker as well as to the grease and other organic matter present; a hard red clinker finally resulted, which, although it contained too much dust to be profitably screened, afforded a fair material for making paths.

"In determining the necessity of harrowing or scraping the suface of these beds, it should be mentioned that operations are not found to be necessary immediately the surface of the beds shows signs of becoming less pervious. So long as the requisite quantity of water can be passed through the bed in a given time, analysis of the filtrate shows that the purification is not impaired, but rather increased, by a certain amount of surface resistance.

"If, however, the upper part of the bed becomes really sodden, then the purification rapidly falls off, and under these circumstances it is necessary to rest the bed and to loosen the surface.

"Examination of the material of the oldest beds a few inches below the surface has up to the present shown the clinkers to be quite sharp and clean. The storm beds, in fact, in their mode of action, and in the character of management required, bear a close analogy to water-works filters."

Date.	Details *re* Quantities Dealt with.							Composition of Sewage and Effluents.										Average Composition of Total Effluent.		Hours discharging over Bell-mouth.
	Total flow of Sewage. (Gallons.)	Excess flow. (Gallons.)	Net flow to be dealt with. (Gallons.)	Total Quantity filtered. (Gallons.)	Particulars of Filtration.			Oxygen Absorption—4 hours. (Grains per gallon.)						Albuminoid Ammonia. (Grains per gallon.)						
					Quantity on Series I. (Gallons.)	Quantity on Series II. (Gallons.)	Quantity on Storm Beds. (Gallons.)	Raw Sewage. Average.	Unfiltered Tank Effluent.	Series I.	Series II.	Storm Beds.		Raw Sewage.	Unfiltered Tank Effluent.	Series I.	Series II.	Storm Beds.		Oxygen Absorption 4 hours.	Albuminoid Ammonia.	
												Contact.	Bell-mouth.					Contact.	Bell-mouth.			
1903.																						
October 8th	95,362,000	2,377,000	92,985,000	33,602,000	16,460,000	4,230,000	12,912,000	3·72	3·52	1·08	1·00	0·40	0·46	·26	·25	·07	·06	·04	·04	2·60	·19	3 E
,, 13th	69,694,000	3,898,000	65,796,000	22,071,000	12,640,000	3,920,000	5,511,000	5·56	3·64	1·22	1·14	0·44	—	·35	·21	·10	·09	·04	—	2·89	·17	--
,, 14th	89,846,000	6,798,000	83,048,000	37,246,000	11,460,000	3,770,000	22,016,000	3·96	2·60	1·33	1·22	0·90	0·90	·21	·14	·11	·10	·07	·07	1·94	·12	3 T
,, 19th	70,938,000	1,578,000	69,360,000	21,224,000	7,840,000	2,200,000	11,184,000	4·60	3·36	1·13	0·70	0·60	—	·21	·18	·09	·05	·05	—	2·72	·15	—
,, 20th	64,699,000	934,000	63,765,000	21,693,000	11,060,000	3,540,000	7,093,000	5·48	4·72	1 31	1·20	0·59	0·98	·24	·25	·08	·06	·04	·06	3·78	·20	1 W
,, 28th	113,815,000	14,351,000	99,464,000	40,582,000	16,020,000	3,950,000	20,612,000	3·64	3·28	0·93	1·00	0·60	0·45	·28	·13	·06	·06	·02	·02	2·35	·09	3 T
,, 30th	69,782,000	484,000	69,298,000	31,561,000	13,680,000	2,300,000	15,581,000	5·04	4·04	1·55	1·24	1·28	1·67	·24	·22	·06	·06	·06	·09	3 06	·16	1 T
November 2nd	94,818,000	12,386,000	82,432,000	38,286,000	18,660,000	3,060,000	16,566,000	3·84	2·72	0·12	0·82	0·59	0·70	·17	·09	·07	·06	·04	·04	1·87	·08	3 T
,, 16th	37,026,000	—	37,026,000	15,129,000	4,150,000	140,000	10,839,000	7·56	5·24	1·93	—	0·75	—	·46	·31	·12	—	·07	—	3·38	·21	—
,, 23rd	40,388,000	—	40,388,000	15,882,000	4,482,000	1,898,000	9,502,000	7·20	5·08	2·27	2·00	0·68	—	·54	·25	·12	·13	·06	--	3·54	·18	—
,, 26th	74,751,000	—	74,751,000	24,211,000	10,458,000	3,942,000	9,811,000	5·56	3·88	1·41	1·32	0·55	0·82	·25	·23	·11	·12	·04	·05	2·94	·18	1 E
,, 27th	65,136,000	—	65,136,000	19,379,000	7,470,000	3,650,000	8,259,000	6·64	4·72	1·63	1·52	0·70	0·98	·34	·28	·12	·12	·05	·07	3·76	·23	1 E
,, 28th	96,298,000	2,660,000	93,638,000	41,327,000	17,098,000	3,942,000	20,287,000	4·28	3·04	1·03	0·96	0·60	0·56	·15	·12	·06	·04	·04	·05	2·02	·09	2 E
,, 30th	39,096,000	—	39,096,000	14,371,000	5,312,000	2,190,000	6,869,000	6·16	4·36	1·34	1·40	0·56	—	·32	·23	·09	·12	·05	—	3·11	·17	—
December 9th	53,014,000	740,000	52,274,000	36,926,000	10,790,000	3,212,000	22,924,000	6·20	5·04	1·36	1·30	1·19	1·33	·26	·17	·10	·07	·06	·06	2·32	·09	3 T
1904.																						
January 13th	75,981,000	3,536,000	72,445,000	40,586,000	19,588,000	4,340,000	16,658,000	6·08	2·40	1·26	1·16	0·85	0·92	·22	·21	·06	·05	·03	·03	1·67	·12	1 T
February 4th	80,866,000	740,000	80,126,000	50,686,000	24,070,000	4,620,000	21,996,000	5·56	5·20	1·50	1·40	0·89	0·91	·21	·18	·09	·10	·05	·05	2·73	·11	2 T
,, 8th	56,423,000	—	56,423,000	41,669,000	20,584,000	4,060,000	17,025,000	4·84	4·88	1·40	1·46	1·44	1·05	·26	·18	·08	·09	·07	·07	2·30	·10	2 E 1 W
,, 9th	40,430,000	—	40,430,000	32,055,000	16,434,000	4,200,000	11,421,000	7·24	6·76	2·07	1·54	1·30	—	·36	·26	·10	·09	·09	—	2·72	·13	—
,, 20th	59,453,000	—	59,453,000	35,513,000	17,430,000	4,200,000	13,883,000	5·56	3·32	1·02	0·96	1·03	—	·11	·11	·04	·04	·02	—	1·94	·06	—
,, 22nd	40,653,000	—	40,653,000	29,142,000	11,288,000	2,240,000	15,614,000	6·64	2·84	1·62	1·40	0·62	—	·16	·09	·05	·04	·02	—	1·51	·05	—
March 14th	62,468,000	—	62,468,000	52,019,000	16,463,000	3,312,000	32,244,000	6·64	5·64	2·07	1·82	1·72	1·88	·26	·10	·05	·06	·04	·05	2·42	·05	3½ E 4 W
,, 30th	63 144,000	—	63,144,000	35,457,000	16,626,000	4,554,000	14,267,000	7·60	5·12	1·83	1·78	1·21	--	·36	·23	·07	·08	·04	—	3·17	·14	--

E—Easterly Area of Storm Beds. W—Westerly Area of Storm Beds. T—Total Area of Storm Beds.

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It should be stated that during the past six months the actual expenditure on these beds has increased, though the average cost per million gallons has not risen proportionately.

I may say that recent experience at Withington has shown that preliminary settlement is advisable before sewage is passed on to the storm beds.

22846. Do you consider storm-water filters lose any of their efficiency by being used intermittently at long intervals?—If once thoroughly matured I think a long resting period might be allowed without detriment. In the early stages, however, it is necessary to work the beds up in dry weather, otherwise they would be a very long time before they would adequately deal with storm sewage.

22847. Have you any practical suggestions for disposing of sludge?—Sewage screenings should be burnt in destructor. The town's refuse destructor should, where possible, be placed at the sewage works. Material from detritus tanks can be tipped without offence, and, after thorough oxidation, could in some cases be disposed of as rough sand. As regards sludge from tanks, I believe that wherever practicable it is well that land should be provided into which this can be dug, as is the case at Birmingham. Methods for drying and utilising the sludge in various ways, either by mixing with lime and selling for manure, as at Glasgow, or recovering grease and other products, as at Bradford and Cassel, have so far had only a limited success. There are, however, possibilities in this direction which have yet to be worked out.

22848. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?—Whatever method is used, it is important that the sludge should not be exposed in an unoxidised condition for any length of time. It should be trenched into the ground at once, or, if lagooned, covered with a layer of peat or such-like material, as at Frankfort. Lagoons of sludge or heaps of pressed cake may readily become offensive.

22849. What, in your opinion, constitutes a good effluent?—A good effluent, in my opinion, (1) does not cause a deposit in a stream; (2) does not deprive the stream of oxygen; (3) does not encourage weeds or fungus; (4) does not contain pathogenic germs; (5) is not injurious to fish, plants, or living organisms.

22850. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—A double contact effluent is generally superior to the effluent from a percolating filter of coarse material, inasmuch as it is not so likely to cause a deposit in a stream. There appears to be little difference between a double contact effluent and a continuous filter effluent if the latter is strained through fine material. I regard the interaction of nitrates and organic matter which goes on in contact beds as of great importance. A continuous filter may often contain more nitrates than a corresponding effluent from a contact bed, but not be so good in other respects.

22851. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—In the first place the amount of dissolved oxygen which the sample is capable of absorbing from fully aerated water. This test, *i.e.*, the "aeration test," may be carried out in different ways. The practice in the laboratory at Davyhulme is to mix one volume of the sample with nine volumes of aerated tap-water and incubate at 80 deg. F. for two days, the dissolved oxygen being determined before and after incubation by the Winkler method. This test appears to me to be the most natural to apply, and an effluent which absorbs only a limited quantity of oxygen under these conditions is not likely to give rise to serious trouble in an ordinary stream. As a further precaution, however, the behaviour of the sample on incubation alone, and the amount of suspended matter produced from it under these conditions, should be noted.

22852. Is one standard for all effluents passing into non-potable streams possible and desirable?—I do not think that one standard for all effluents passing into non-potable streams at all possible or desirable.

22853. Should there, then, be more than one standard: and, if so, how should a plurality or series of standards be formulated? What amount of suspended matter would you allow in an effluent?—I consider that each case should be carefully and scientifically considered on its merits, regard being had to the conditions at the point of discharge.

22854. What is your experience of the effect of storm water upon filters of various sorts?—Provided that the storm water is settled before passing on to the beds we have not found any permanent damage to be done, though in long-continued wet weather the maintenance charges certainly rise and the efficiency of the filters is for the time somewhat impaired.

22855. How far do you consider it advisable for a sewage installation to be worked automatically?—I do not consider that automatic working is desirable or useful in large works. In the case of small installations some simple form of automatic apparatus is often useful, but rather with the intention to minimise supervision than to dispense with it altogether.

22856. Have you made any systematic observations as to the effects of discharging effluents of known volume and known composition into ditches, canals, brooks, or rivers of approximately known volume?—I have found that even with effluent from first contact beds the condition of the Ship Canal is improved from the point of view of putrefaction below the Manchester outfall, although the analytical figures, *e.g.*, 4 hours' oxygen test, are somewhat greater below the outfall than above.

22857. Could you make a short statement setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents, and giving your reasons? What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—I may here refer to my lecture, "The Application of Chemical Analysis to the Study of the Biological Processes of Sewage Purification," delivered at the Public Health Laboratory at the University of Manchester, March 14th, 1904, a copy of which I hand in. (Published by Sherratt and Hughes at the University Press, 27, St. Ann Street, Manchester.)

22858. Are there any further points on which you would wish to speak at this stage?—I am of opinion that our knowledge as regards the physical and chemical changes which take place in the course of the purification of sewage is still very far from complete. A large amount of careful work is needed in a number of directions, of which the following in particular may be instanced, viz., to determine:—(a) (1) What is the purely physical effect of contact material of different sorts and sizes on solutions containing the substances found in sewage or produced during its transformation? (2) To what extent is anaerobic action desirable, and what are in fact the precise changes which occur when the various substances present in sewage are subjected to anaerobic fermentation? (3) The actual quantitative proportion of the organic matter which can be converted into simple products, either gaseous or soluble, in water by anaerobic and by aerobic change. (4) How far the changes taking place in a biological filter are to be classified as purely chemical, or as being produced by bacterial activity, or by the activity of higher animals and plants. (5) What are the precise effects of sewage and the various products of its transformation on the life present in streams, whether microscopic or otherwise? (b) I consider it very important that the laws for admission of trade refuse into sewers and watercourses should be clearly defined. (c) I feel strongly the importance of the adoption of a broad policy in sanitary administration. Municipal financial resources being necessarily limited, care should be exercised that expenditure should be to the best advantage: thus, for example, it may be of more importance to the health of the community that money should be spent in obtaining good housing accommodation and adequate open space than in producing a sewage effluent of an irreproachable character. I believe also that the rivers would be in better condition if authorities endeavoured to cope with the whole of the first flush of storms by settlement or otherwise, even if this were done at some sacrifice of purity in the dry weather effluent. Each locality will have to judge for itself how the available money can be most wisely spent, and what is the limit of necessary expenditure. (d) It appears to me to be increasingly necessary that towns should derive their water supply from sources beyond the reach of pollution. It would appear that more might be done in the way of utilising ground water supplies, as has so successfully been accomplished at Frankfort. Where the source of water is exposed to pollution from sewage, or ordinary sewage effluent, it should be carefully filtered. There are possibilities in the use of stone as a stand-by in the case of temporary breakdown of the filters

Sewage from infectious diseases hospitals, or from individuals suffering from infectious disease, should be sterilised before admission into streams. (e) A recent visit to the Government Experimental Station at Berlin has impressed me afresh with the great importance of the formation of a central authority such as has already been suggested by the Commission. Such an authority should have ample means and opportunity for carrying out the numerous careful researches which are needed if sewage purification is to be carried on throughout the country with efficiency and economy. In conclusion, I should like to thank the officials of the Rivers Department and the staff at Davyhulme for their help in preparing the information required for answering the foregoing questions, and in particular I should mention my chief assistant, Mr. Edward Ardern, now resident chemist at Davyhulme; Mr. Stanley Royle, engineering assistant; and Mr. David J. Hallard, rivers inspector.

22859. (*Sir William Ramsay.*) Mr. Fowler, in Quesion 22727 you give the quantity of iron in solution coming from the galvanising works as practically 18 per cent of the liquors?—Yes.

22860. And then you give the gallons per day coming from such works as 550,000, galvanisers and brass finishers?—Including cooling water from wire rollers.

22861. Is the large proportion of the water cooling water?—Half a million of it.

22862. Is cooling water?—Very nearly that.

22863-6. Then what amount would you say is the solution which contains the 18 per cent. of iron?—It is estimated at 1,600 gallons, the remainder of the 50,000 gallons being washing-off water, containing a smaller percentage.

22867. Is it not possible to get the galvanisers to recover that iron; it is a very large proportion?—We have approached them with that object, and they say that they have spent a great many hundreds of thousands of pounds in fruitless experiments, and they do not seem to wish to go much further with it; but we still have hopes that something may be done. I may say that we have very greatly reduced the percentage of iron in the Manchester sewage by dealing, or causing the firms concerned to deal, with large amounts of iron in suspension from aniline production which used to go into the sewers, and speaking from memory the percentage of iron oxide in the mineral matter of the dried sludge was reduced thereby from about 50 per cent. to something like 25 or 18 per cent. Those figures are given in the last published report, published in March 1904, so that we have made a very great reduction, but there is no question that there is a very large amount of iron in the Manchester sewage which constitutes part of the sludge—as I say about 20 per cent. of the total mineral matter in the sludge is iron oxide.

22868. (*Mr. Power.*) In the septic tank sludge, you mean?—Something like that, I think; I have not got my report here, but at any rate the figures can be verified from that, and in the matter which is washed out from the beds, suppcsing we take the material of our beds and wash it up, a very large proportion of the mineral matter is oxide of iron.

22869. (*Sir William Ramsay.*) Then of course you have no chance of getting sulphuretted hydrogen under any conditions in the septic tanks?—I think not, unless they are allowed to stand for some time. I have made a point of that in my evidence; that it is important, if you are not to get nuisance from septic tanks, that the sewage should not be long in passing through, or that it should not be allowed to stand, and it happens curiously that only the other day, owing to certain constructional work, we had to stop the flow through our septic tanks for some days, and the manager at once complained that the stench was becoming rather serious.

22870. Of course the iron which is present is ferrous salts?—To be sure.

22871. These will oxidise when exposed to the air but not in the septic tank; they may be reduced in the septic tank?—They may be reduced in the septic tank; in the sewage they are mostly present as ferric salts.

22872. Ferric?—Unless a large gush comes down at once; but if you have an ordinary sample of sewage apart from these occasional flushes, you will see most of the iron will be there as some kind of ferric hydrate.

22873. Colloidal?—Colloidal; iron in the ferric state. Of course it is there mostly in the ferrous state originally, and as it goes down the sewers and comes into contact with the air it rapidly oxidises. *Mr. Gilbert J. Fowler, D.Sc., F.I.C.* 12 May 1905.

22874. And probably will not be attacked by the sulphuretted hydrogen when it is in the insoluble ferric state?—I think probably it would be; all that iron material quickly blackens with sulphuretted hydrogen.

22875. It would be a very important thing to put pressure upon those people to try to avoid such a thing as that?—Oh, a very important thing indeed. I may say, as possibly of interest in this connection, that the black suspended matter which passes away from the septic tanks certainly contains a large amount of sulphide of iron; if you allow it to oxidise it goes red, and you can extract something like 10 per cent. of free sulphur from it; I have sent up to some of the works in Manchester to see whether they could recover the sulphur, but they said there was a fair amount of sulphur there, but any idea of burning the stuff to get SO_2 would be of no value, because of the large amount of carbonic acid from the organic matter present which was given off at the same time.

22876. In answer to Question 22723, the second regulation for admission of refuse into sewers in sub-section (*c*) requires that the resultant effluent shall be free from solids in suspension beyond fifteen grains to the gallon; do you think that is as low as it can be conveniently got?—Well, you see one had to average that figure. That figure is more or less of a rough practical guide rather than a severe limit, because, for example, ordinary sewage, normal sewage, will contain more than that. On the other hand there are certain effluents which the manufacturers would have difficulty in getting down to that figure; other effluents there are, on the other hand, which they can readily get much below that; and so we put that in as a rough average, with a reservation that certain effluents might find it difficult to come within it; but on the whole it has worked very well, and I have found in a great many cases where the chief problem has been to get rid of the suspended matter the manufacturers have had no difficulty really in coming within that limit.

22877. Then in the regulations for the admission of trade refuse into sewers in the city of Manchester, there is a provision that the drainage shall be conveyed into the sewer at a uniform and regular rate of flow throughout the twenty-four hours of every day. I wish to ask is that regulation pretty well kept?—Oh, yes.

22878. You do not find difficulty in that way?—We have no serious difficulty in that way; it is simply a question of providing the tanks with floating arms.

22879. In your answer to Question 22729 you state the method of starting new beds, half-acre beds; "Half-acre beds which after several weeks working failed to give a non-putrefactive effluent when only filled six times a week, two hours contact being allowed, immediately gave non-putrefactive effluent when the period of contact was increased to twelve hours." We have had evidence to show that that is not always the case. Do you find it uniform that this is so, or is it the result of some special experiments?—It is almost uniformly the case immediately at the beginning of the working of a bed, and certainly in the case of the beds above mentioned, which had been working a few weeks. My further experience has led me to think that the whole thing is a purely physical question at the very beginning. It is possible that a slightly different impression is conveyed by this answer from what I would now wish to convey. I mean quite this—that with the absolutely new material you put sewage on to it, or effluent on to it, and hold it in contact for a prolonged period; then almost all the colloidal matter in the effluent is retained by what some call absorption, physical absorption by the medium, and you get a wonderfully clear filtrate, even after the first contact, if the contact is sufficiently prolonged, and that will go on for some time until there is a certain amount of accumulation of this colloidal matter, and then the bacterial activity is not sufficient to prevent a slightly increased putrescence in the nitrate. I do not know if I am making myself clear, but the first change appears to be purely physical; then some time must needs elapse before the bacterial activity will begin, and before this colloidal matter begins to be

properly oxidised; and there is an intermediate stage when you will not get perhaps such good effluents. You get a very good effluent at the first, and you get a good effluent when the bed is matured, and there is an intermediate stage, it seems to me, when you may fail to get such a good result.

22880. How long does this intermediate stage last as a rule?—Well, that will depend on the season of the year to a very large extent. It is always better to start beds in the spring if you can; I think there is no doubt about that from our experience; but with the Manchester sewage under the best conditions I should think it will take you some three months before you can begin to get nitrates in it.

22881. (*Mr. Power.*) Even under this plan?—Even under this plan.

22882. Have you applied the plan generally to sewage with a view to rapidly maturing beds—to domestic sewage—or do you think it is peculiar to Manchester?—I think I would be inclined to apply it generally, because you see you at once get an idea in that way when to start your work, whereas otherwise you may be going on forcing a good deal of colloidal matter through, and at t same time not be getting your bed into condition as fast as you otherwise might.

22883. You might be losing colloidal matter?—Yes, passing right away unpurified.

22884. (*Sir William Ramsay.*) A little further on you say, "With beds which have been in use for several years the total period of filling, standing full, and emptying, need not exceed two hours;" but you do not mean to say, surely, that you have two-hour cycles; you give a period of rest, do you not?—Oh, yes. My point was that I would keep my period of rest as long as I could, but not be so much concerned about my period of contact.

22885. I see—period of rest empty, that is?—Empty.

22886. In your reply to Question 22735 there is a curious remark; perhaps you would wish to modify it. "It appears to me that, on the whole, the strength of sewage is best measured by the number of gallons per head arriving at the works daily." It does not appear to me that the amount of sewage has anything to do with its strength?—Pardon me.

22887. You can measure strength in one gallon of sewage, or in one million gallons; it may be the same strength?—Yes; there comes the question as to what you mean by "strength."

22888. What do you mean by strength?—Well, I mean just what I have said; that is to say, I notice there is a copy of my lecture there. I might refer to the case in point, where I quote the case of latrine sewage in Calcutta, with which you are doubtless familiar.

22889. Yes?—Page 11 of my lecture; I give here the actual figures of Johannesburg; some of the Johannesburg tank-cart sewage, and there there would be a very small amount of water in proportion to the organic matter, and you get what I call a very strong sewage, namely, with thirty parts per 100,000 of chlorine, and from six to twelve parts of albuminoid ammonia, you see.

22890. May I suggest that the words "of population" after "per head" will make it all right, so that it will read "per head of population." I think that is owing to a misunderstanding of what is meant by "per head"?—Oh, I see; yes, just so.

22891. Shall we insert the words "of population" there to make it clear?—Very good.

22892. Now I understand, of course.

22893. (*Colonel Harding.*) Might I interrupt Sir William for a moment to ask a question on that point. It occurred to me that if it were possible to measure the strength of sewage in the number of gallons per head coming to the works that would be extremely convenient. If one could speak of a 45-gallon sewage and a 25-gallon sewage, and form by that means a measure of the strength, it would be invaluable, the suggestion being that the larger the number of gallons per head the weaker the sewage would be; that is so, is it not?—Undoubtedly.

22894. I have endeavoured to follow out your suggestion by comparing sewages with which you will be familiar. I have taken Manchester, Heywood, Salford, and Burnley, and endeavoured to see how that would work parallel to the albuminoid ammonia measure?—Yes.

22895. I am obliged to leave out Salford, because I see they do not give the albuminoid ammonia measure; they only give the oxygen absorbed. Leaving out Salford, I find that Manchester is a 45-gallon sewage, Heywood a 30-gallon sewage, and Burnley a 27-gallon sewage?—That is so.

22896. Well, judged by the albuminoid figures given by those several authorities, in the case of Manchester, which has the highest number of gallons per head, we have 0·55 albuminoid; then for Heywood, which has thirty gallons per head only, we have 0·8; and for Burnley, which has twenty-seven gallons only, we have 1·1. So that your system of measure would seem to be in general harmony there with the albuminoid ammonia measure?—I think it would be. I may say perhaps that in practice I have come to the conclusion that in designing works one should deal, not with the volume but with the population, and calculate your tank space and your filter space at so much per head of the population, and then you are quite independent of the varying water supplies.

22897. Of course in taking the gallons per head as a measure of the strength of sewage, one is obliged to take so many things into consideration also?—Of course.

22898. First, the volume of trade effluents, the subsoil water, and how far water closets are general in the community?—To be sure; I think I have made that qualification.

22899. If one has to do that, then is there much value left in the gallons a head measurement; is it not really safer, and does not one get quicker to the point, if one takes the measure of the albuminoid nitrogen as the measure of the organic impurities?—Unfortunately in designing works you have not any figures of that sort as a rule to go upon; there is no sewage to analyse, you see.

22900. That observation, no doubt, applies to entirely new works?—To be sure; of course it is simple, no doubt, when it is a question of the extension of an old works, but I have been concerned lately with designing schemes absolutely *de novo*, and that is the only way that I can get at it.

22901. Anyway, your suggestion is an interesting one; it will be useful to work it out and see how far it may be taken as of general application.

22902. (*Sir William Ramsay.*) Have you tested for mineral poisons in your sewage and effluents?—No; only so far, I know that sulphocyanates are present.

22903. Nothing more; no arsenic?—I have never tried, I am bound to say.

22904. In your reply to Question 22741 you say: "The addition of chemicals in time of storm I do not consider to be of much, if any use." By chemicals, do you mean the sewage chemical precipitants, ferric cake and ferric sulphate, and so on?—That is what I mean. I may say on one occasion I added for the sake of experiment as much lime and iron as I possibly could, when there was a big storm flow on but I do not think I did any good.

22905. In answer to Question 22746, you refer to certain tanks, which tanks, "by continuous settlement, from three to four hours being taken in passing through the tanks"—the septic tanks?—I think it was under the head of sedimentation tanks.

22906. Sedimentation tanks?—Of course, it does not come out here, but in these questions that were sent, they were divided under certain heads.

22907. You say in answer to Question 22749 that you prefer to use settlement tanks in parallel. What are your reasons?—My reason briefly is this—that beyond a certain length of tank the amount of added settlement that you get is very small, and moreover there is greater difficulty in cleaning the tanks one after the other.

22908. The first tank will be filled inordinately?—To be sure, though I ought at the same time to qualify that by saying that sometimes it is an advantage that

your first tank should be filled inordinately, as you have said. For instance, at Bradford they work their tanks of set purpose in that way, so as to get an enormously concentrated sludge in their first tank for the purpose of grease extraction, and where that particular purpose is required, then no doubt there is a useful purpose served.

22909. In answer to Question 22752, you speak of passing the grit in with the rest, and sending it through the ejectors or sludge pumps. Does not the grit damage the sludge pump?—No, not so far as we know.

22910. Would you screen the sludge before you pass it to the pumps? A little further down, you say that "in Manchester the exceptionally large amount of cotton waste and other fibrous material in the sewage renders it necessary to screen the latter"?—To screen the sewage. My point was that in some places, as for instance in Birmingham, you can satisfactorily screen the sludge, but I do not think that would be practicable in Manchester.

22911. Are there any houses near your works. You speak of no complaints of nuisance, but are there any houses the householders of which could complain?—There are very few close to the works; there is the manager's house on the works, of course. I am bound to say that he has not an ideal time, but then his house, I think, is badly placed, because it is just at the entrance to the works, and occasionally, at the inlet from the screen-house, you do get smells, but they do not get away to any distance.

22912. In answer to Question 22759, you speak of mixing by baffling-boards or otherwise, but not to such an extent as to break up the precipitate into a very finely divided state. Have you experience of this happening?—Only so far as this—that when I have experimented with ferric salts I have noticed that we have got a very finely divided precipitate, and that finely divided precipitate took a long time to settle; therefore I inferred that if you beat up any other precipitate into that same degree of fineness you would not get it to settle quite as well.

22913. In the Table in 22763, phosphoric acid is returned as 0·17; should not that be 0·71. That is very low?—I have not got the original report here with me, but I am afraid this is correct.

22914. It is very low?—It is low, I know.

22915. In answer to Question 22766, you use the expression, "worked over." What does that mean—removing the fine deposit?—What I mean is that that fine deposit has been through the various processes of bacterial digestion; it has been worked over by the bacteria.

22916. Oh, by the bacteria, yes. In the extract on the working of the open septic tank (Question 22775), there is a sentence: "The result obtained by the careful measurements recorded in the foregoing paragraphs is thus confirmed, viz., that rather more than one-third of the total suspended solids in the sewage will have to be dealt with as sludge in the septic tank." Is it not very much more than one-third?—That we have actually to deal with?

22917. To deal with?—It depends simply upon how much you allow to pass away.

22918. But in practice what happens?—In practice I may put it in this way: We used, in the old days of chemical treatment, to send away an average of three and a half trips of our steamer per week; we have now reduced that quantity to two and a half trips; but in those two and a half trips you have, of course, included a large proportion of the sludge that is brought down in storm times and deposited in the storm tanks; and, therefore, it is a little difficult, unless I actually get out the whole figures from the septic tanks—which I am bound to say I have not at my finger ends—to say exactly what amount is taken out from the septic tanks alone. I think, speaking very generally, that we do take out as a matter of fact about two-thirds instead of one-third of what we used to. I should think that would be safe. But, of course, we do that for this reason, that we find that it is economical not to send so much suspended matter on to our beds. The whole question of sludging resolves itself into that—how you will deal with it; if you find it economical to deal with a certain amount of it on your beds by scraping it off or by washing at long intervals, then you will spend more on your beds and less on your tanks. If, on the other hand, you are concerned to prevent your beds from receiving any suspended matter at all if possible, or if you try to work things so that they receive an effluent with as little suspended matter as possible, then of course you will obtain more in your tanks and spend more on your tanks.

22919. Do you vary your treatment, or have you found the conditions suitable for Manchester?—We have come pretty much to this conclusion, that it is not with our present beds at any rate economically advisable to allow more than eight grains per gallon; that is to say, about ten or eleven parts per 100,000 to pass away on to our beds, whereas these figures allowed for considerably more than that.

22920. In the same extract, under the head "The amount and nature of dissolved solids," you use the expression "Research in this direction is being continued;" have you made any further experiments since this was written?—There is a paper, I may say, coming out in the forthcoming Society of Chemical Industry Journal on the question of these colloids; we have found one outstanding result which is rather of interest, namely, that if you compare Manchester sewage with say Moss-side sewage, which is entirely domestic, comparing the two as regards the proportion of the oxidizable matter which passes through the dialyser, there is a very much larger proportion in the case of Manchester than in the case of Moss-side; you get a curve in the case of Manchester something like that (*indicating*), you get in the case of Moss-side a curve something like that (*indicating*), so that you get a very sharp means of distinguishing between the oxidizable matter of a practically harmless character and that due to sewage.

22921. The Manchester oxidizable matter being very largely ferric salts?—Mostly sulphocyanates and phenols.

22922. No ferric salts?—No.

22923. Again in the extract under the head "General Observations and Conclusions," you say "liquefying or converting into gas about 25 per cent. of the total suspended matter." It really means digestion comes to about 25 per cent. of the total suspended matter. Do you still adhere to that figure?—I am afraid I do not feel competent to express myself strongly on that point, because we have found that these changes are so very complex; that is to say, if you take septic tank effluent which is moderately clear at the beginning and allow it to stand in a closed bottle it will deposit an enormous amount of stuff, and we have found so far as our dilution experiments have gone—I do not like to speak positively because we have not done very many—but so far as we have gone they agree in this, that there is rather more colloidal matter in the septic tank effluent than in the raw sewage, but then Manchester sewage is quite special in its character, we must always remember.

22924. In reply to Question 22822 you give an opinion as regards continuous filtration; is that opinion the result of practical experiment or what you have seen?—The controlled filter.

22925. The controlled filter?—It is the result of practical experiments.

22926. By yourself?—By myself on a small scale; that is to say, I find I get absolutely identical results whether I distribute by means of a fine layer of material or by means of a distributor: that is to say, at a certain rate; naturally you can not pass quite such a large amount through, and I go on my general experience of other places. I know of works—I know Friern Barnet, for instance, which is one of the oldest works in existence which has gone for fifteen years or more without any difficulty at all—yielding a beautiful effluent; I know of other works of the same class round Manchester—very fairly large works, as the Flixton works, for example—which do extremely well.

22927. In answer to Question 22794: "What do you find to be the best filtering material." You say that vesicular material is better than non-porous. We have had answers from other witnesses suggesting that non-porous material is better, because it is more easily

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cleaned ?—Non-porous ; but I draw a distinction between a porous material and a vesicular material. I do not know if I make myself clear ; for instance, coke is porous ; it has a large number of very fine pores which are immediately clogged ; a vesicular material has large holes and cavities in it.

22928. Which do not get clogged ?—Which do not get clogged ; that is what I mean ; at the same time giving you a large surface.

22929. Then in answer to Question 22795 you speak of water-logging ; have you experimental proofs of this ; I think it is the first we have had mentioned ; I do not know that we have had the expression "water-logged" before in connection with a filter ; one knows filters get stopped, but I have never heard of them getting water-logged ?—There is the one-acre filter at Barking, a case in point, for years that has been water-logged, at the bottom.

22930-1. Does that mean that it is stopped at the bottom?—That is what I understand. It gets impervious at the bottom and fills up. It simply will not drain from the bottom, the bottom layer of that filter—I am not sure that it is not published in a report—has become completely consolidated ; and I have noticed this, that whenever in our ordinary beds by some carelessness in putting in the material, a certain amount of fine stuff has got in—there may be a layer of it just at that point—the water remains and will not get away. That was particularly the case with one bed ; and to watch this process I had pipes sunk at various points, and wherever there was a bad patch the water would stand in the pipe, although at other parts of the bed it might be quite free.

22932. Passing on to Question 22801, you say that one cubic yard of material should be provided per person ; would that also apply to a percolation bed ?—I think so, for this reason, that, further on, I show that as far as our experience goes—of course, I can only speak from my own experience, but I have also got figures from other places which seem to bear it out—that you obtain only rather more nitrate from a continuous filter, when you try experiments on absolutely comparative lines. For instance in Manchester, what we did was this—we had two measuring boxes about two feet square by eighteen inches deep into which we put the effluent we were going to experiment with, absolutely the same in both cases. Then, we had two experimental filters under those of two feet square and three feet deep, one fed by a little Stoddart distributor very carefully adjusted, and the other worked as a contact bed ; and below that again we had boxes to receive the whole of the effluent, first flush, and everything, so that we got an absolutely true comparison, and—I have given you the figures later on—you will find that the continuous filter gave slightly the better result from the point of view of putrefaction and the production of nitrates, but that there was comparatively little to choose ; and that, and my other observations of other places where accurate comparative experiments have been made, lead me to think that the whole thing is really a matter of surface and air supply.

22933. (*Chairman.*) On Question 22716, does the surface water from the areas which have not been built over enter the sewer ?—" What is the drainage area. . ."

22934. Yes, exactly. Well, my subsidiary question is, does the surface water from the areas which have not been built over enter the sewer ?—No, there are no sewers, I understand ; these districts are, for instance, Heaton Park. Heaton Park is a huge park which has recently been brought into Manchester, and it is a large tract of purely agricultural land, you see, but the Engineer will be able to deal with that question fully. The unbuilt areas are very largely open tracts of land which are not sewered at all.

22935. Quite so, but does the surface water from them get into the sewers ?—No, not into the sewers.

22936. Oh, it does not get into the sewers ?—Oh, no.

22937. Then Question 22722, do you mean in your answer that the overflows do not come into operation until the flow is five times the maximum rate or five times the average rate ?—They were designed—I have not said what they do—they were designed to come into operation at a dilution of five to one on the average rate.

22938. Then on Question 22725, you say the volume which passes over the overflows cannot be accurately stated ; can you give any approximate figure ?—Well, we worked at this with some care, and we hardly like to commit ourselves ; but, quite approximately, of course, one might get at it by adding to the dry weather sewage the rainfall and subtracting the twelve or thirteen thousand million that come down to the works. One could make that calculation and then one will obtain——

22939. (*Colonel Harding.*) Six thousand million gallons about ?—Six thousand million gallons. Somewhere about that.

22940. (*Chairman.*) Would you put it approximately that 6,000,000,000 gallons went over the overflow ?—Not 6,000,000,000 gallons ; some of it no doubt would go over the overflows, but a large amount would not get into the sewers at all—would form sub-soil, water and so forth.

22941. Then Question 22741, you say that no doubt a good deal of mud passes on to the beds in time of storm ; do you suppose that causes much serious choking ?—I do not think so, because the greater part of it remains on the top and is afterwards scraped off. I may say, to anticipate perhaps a little, I have only this morning got some of the recent measurements of capacity from our beds, which seem to show that no serious chokage has taken place. When once the bed is allowed to drain and dry in fine weather there is no evidence of anything serious having happened.

22942. And in answer to Question 22743, you say the suspended matter carried by the stream is injurious either owing to its clogging the gills of fish or blocking up water works filters. Have you any experience of water works filters being blocked up in that way ?—No personal experience, but it just occurred to me that that was one of the things which would have to be considered ; for this reason, that, of course, if you take a water works that I am to some extent familiar with, the water works at Hamburg where they take the water of the Elbe, and settle it in tanks, and then pass it on to filters, of course unless you had an enormous tank area to allow of a very long subsidence finely divided clayey matter would undoubtedly pass away from your settling tanks, I should imagine ; it is more supposition on my part than actual experience, I am bound to say, but that is what I had in my mind.

22943. You do not of your own personal experience know of any case ?—No.

22944. You have no experience, so to speak, in what distance a river will get rid of the suspended solids that have been thrown into it ?—Of course, that involves a very large number of questions. I know from first hand information that in the case of the sewage of Hamburg, when that is first discharged there is a certain amount of deposit on the bottom of the river ; then the tidal flush comes and sweeps it all away immediately afterwards ; there is nothing left ; and, of course, I am thoroughly familiar with the state of affairs at the Rathmines outfall in the Liffey, and there, there is evidence that with the outrush of the tide everything is taken right away ; but then, almost every river and every estuary varies ; and I have put it in this way that one has to find out what the river is capable of carrying in suspension, and anything beyond that must, of course, be deposited sooner or later.

22945. I mean you have not actually any experience of a river and its powers of digestion ?—No ; no personal experience other than this particular case of Rathmines, which I have had occasion to go into very carefully.

22946. Question 22760, you say an average analysis of the effluent from chemical treatment for the quarter ending December, 1902, gives such and such results. What was the chemical treatment ?—Lime and copperas treatment it was.

22947. And what was the amount of the chemical you added ?—In 1902, speaking from memory, there would be about from two to four grains of lime and about two grains of copperas ; but, of course, there again I must make the distinction between Manchester and other places because Manchester sewage is very largely precipitated

by the various chemicals in it before it gets to the works at all; as it comes down to the works you can see it all flocculent in the sewer.

22948. Then Question 22772, to what extent do you pass storm sewage through your tanks?—Through the septic tanks?

22949. Yes?—Well, I know that Mr. Wilkinson has worked that out very carefully, and it comes to a very high rate at the maximum; but it is only fair to state that our works are not yet completed, and owing to the present arrangements we are bound to pass more through the septic tanks than I think is altogether desirable because there is nowhere else to put it. It will run through probably in three or four hours; but I know Mr. Wilkinson has gone into that carefully himself.

22950. (*Mr. Power.*) What is the maximum flow through a septic tank in time of storm you are proposing to allow when you get your whole works completed?—I should say six hours, roughly speaking.

22951. And at that stage you would turn the sewage into the settlement tanks?—As matter of fact it is going through every tank we can get hold of at the same time.

22952. I mean when, under the completed process, the flow is more rapid than six hours; then you will turn your sewage into the settlement tanks?—In practice it is impossible to make a distinction of that sort, because a storm will come down on you rapidly and the whole works begin to run at an increased pressure, and I know of no method by which you can say, "Now we will pass so much through these tanks and then we will stop and go on with our settlement tanks," when you really are faced with a storm.

22953. It is left to the judgment of the man on the spot?—It must be, I think. A great deal of management is required. In one or two of my answers to these questions I have indicated how we have endeavoured to cope with things when we have had to deal with a storm.

22954. But you would prefer not to exceed a rate of six in the septic tank?—I should prefer not to; of course, in practice what we should do, and what we do—as a matter of fact, we pass it through the septic tanks until we have got so many beds filling at once, and we give a general instruction that no more than a certain number of beds shall be filled at once; that represents roughly a certain rate of flow; but, of course, sometimes you have, as I say, to take what comes; you cannot always stick to your general instructions; but when we have got our completed arrangements, that is what we shall endeavour to do—not to exceed a certain number of bacteria beds filling at once; but then at the same time, of course, we are always passing some on to our storm beds. I am afraid it is impossible to make actual distinctions for the reason that I have put down—I have not got the questions just in front of me—but unfortunately we have an enormous volume coming down all at once and the whole of it is fairly strong.

22955. It comes down to you at a very great rate for a short time, you mean?—Just so.

22956. And you have to accommodate it somewhere?—We have got to deal with it as best we can; and practically what I have done on several occasions is this: I have by hook or by crook—if I may say so—coped with the immense rush of the first few hours and then the whole of the sewers have got thoroughly cleansed and the sewage is beginning to get dilute, for instance, if the storm has been going on all day, I have on more than one occasion given instructions to shut down all the filter beds and to allow what comes after simply to stream through the sedimentation tanks and not be filtered at all, because although you send away a certain amount unfiltered in that way, and although you may be working for a short time your whole works at a rate which is far from any calculated rate that you may have originally intended, yet the ultimate result, I think, is for the best, because you purify to a greater or less extent the worst part of the sewage and then you allow your beds a period of complete rest to get over the very hard work that they have had to do.

22957. That is an important consideration *qua* the beds to give them the rest afterwards?—On one or two occasions I believe that that has saved the situation. I remember perhaps the worst experience that we had was a fall of snow in April, I think it was, which, of course, as soon as the sun got up melted all at once, and the whole of it came down upon us, and we had to cope with it, because there is no outlet from our works; it had to go through the tanks and there was no way of sending it away, and consequently the beds certainly had a very bad time, but towards the end of the day I gave instructions; I said, "Now you must shut off all the beds and through the whole of the night allow the stuff to pass away simply with settlement," and in the morning, to my great relief I found the beds were in a very fair condition; but I think it was just that complete twelve hours' rest which saved the situation.

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22958. In reply to Question 22747, you give a Table as to the results of quiescent settlement of dry weather sewage; have you any corresponding data for storm water sewage?—Yes, I think you will find it; I do not know whether I have put it in here, but we made a number of determinations with storms.

22959. Two and a half hours settlement—total suspended matter 4·2?—Yes.

22960. Have you thought of quiescent tanks for storm water, suppose it was practicable to have them at Manchester?—If it was practicable I am quite sure you would get better results; still, I have a number of results for storm water amongst my notes, but I do not think that particular question was asked here.

22961. Would there be advantage, do you think, in dealing with storm water by quiescent settlement similar to that shown in your Table to have been obtained with the dry weather sewage; the Table shows an enormous reduction in two and a half hours?—Oh, that will be so; well I can tell you at once from memory, because it was given in evidence I think before the Local Government Board; we found that in half an hour, I think I am right, nearly 90 per cent. of the total suspended matters in storm water settled. Of course, they are of a very heavy nature, and they drop almost at once. We made a number of careful experiments on those lines in designing the storm water plant. That gave us confidence that a very quick passage through tanks would remove from storm water a very large proportion of the suspended solids, and that is no doubt the case.

22962. The supernatant liquor from such quiescent tank cantaining storm-water would be chemically unobjectionable; it might go straight into the stream without going through your storm bed?—In many cases yes; only you will have this difficulty of the first flush; as I think I have said in one of these answers, if you could get the whole of your storm at once to mix it in one huge tank to let it settle, then what was sent away would be all right, but unfortunately of course you cannot do that, and as a matter of practice you find that there is no relation in our—I am speaking carefully—there is no relation in our experience between composition and volume. You may have your sewage, as I know, very carefully observed, the sewage may be running down to you beyond your six times increase of volume, and yet it will be foul sewage.

22963. Strong sewage?—Yes, because all the sewage in your sewers and all the deposit is swept up into a sort wave.

22964. It comes in front of the other?—It comes in front of the other.

22965. (*Chairman.*) On Question 22777, at the end of your answer, you say the "operation need not be offensive, and the dried sludge can be sold to farmers, especially if mixed with lime." Well now, do you find that any particular precautions are necessary to prevent the process being offensive?—Well, we find that the particular trouble that we had was with certain tanks which had been allowed to go on for a certain period without any of the sludge being taken out, whereas if you can take it out in small quantities at a time and take it out in such a way that you do not mix in a large amount of what you may call undigested sludge, that there is no trouble at all; because it was only with two tanks which were not designed as septic tanks—which were only ordinary settlement tanks, used temporarily as septic tanks—and that we got all the sludge, through some curious circumstance in the flow of the sewage, heaped up at one end, and consequently we got that

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enormous mass of half digested sludge which had retained a lot of gas; as soon as it got a free vent all this gas came out, whereas with our ordinary septic tanks, which enable us to take it out in small proportion at a time, we have never had the same difficulty.

22966. Then Question 22789, you say that "it is possible to remove the greater part of the visible suspended matter from the effluent before passing on to contact beds by covering a portion of the surface with a thin layer of fine material." Do you find that that has any tendency to check aeration?—No, I cannot say that it does if it is kept clean, of course. We have experimented a good deal as to the best form of covering. If you cover the entire surface then you get a water-logged surface, but if you only cover a part, and if you keep that fairly constantly scraped and attended to, we have found no difficulties in that way. I have tried several experiments with beds covered partly in that way as regards the formation of nitrates, and if anything we got rather more from them than from others.

22967. Question 22790, in the matter of the treatment of the Withington sewage, do you think that there would be any objection to a closed septic tank there?—I am doubtful whether it would greatly help matters, because, unless you have a tall shaft, you get the smell concentrated at the exit; if you take it up in the shaft then that attracts everybody's attention to the place, and whether there is a smell or not I am afraid you very likely would have complaints.

22968. Question 22792, may we take it that you think that a cubic yard of a contact bed, say 2 feet deep, is as efficient as a cubic yard of a bed which is, let us say, 4 feet?—Unquestionably, taking always the same size of material. All these comparisons must be with the same size of material.

22969. But the question of depth makes no difference?—Within the limits which I mention here.

22970. Then Question 22797, does your answer imply that you know of any cases where it is desirable to put the crude sewage straight on to the bed?—Yes, I do as matter of fact.

22971. You do?—I have been consulted about cases where freedom from nuisance is absolutely essential, and where a nuisance was complained of (where I am bound to say, I personally should not have thought that anything was happening at all), but freedom from nuisance was of the first importance, and in that case I know of no method of dealing with sludge to absolutely avoid nuisance other than the pure aerobic method.

22972. In the next question you say that in certain cases a very short contact, say a quarter of an hour, is all that you require; that you have found by experience?—Oh, yes.

22973. On Question 22819, you give us the results there of some experiments; did those experiments extend over a considerable time?—Oh, yes, they are the average of a very large number of results.

22974. They are?—Yes, the first one, or rather the last, the 6 foot filter went for several years.

22975. Then Question 22827, as to the percolating filters: you say that your experience goes to show that aeration takes place from the top and not from the side. Have you made prolonged observations on that point?—Well, what led me to that opinion was really this, that with these filters which we had—I may say it was the Stoddart experimental filter—when it began one side of it was partly closed by a bank, and I had left it so on purpose for the reason that I thought that in a large installation the interior of your filter must necessarily be a long way from the outside air, and this was a filter perhaps as big as twice these two tables (*indicating*) and I got certain results and they were not very good, and the quality of the results was put down to the fact that it was not open on all sides, so I had the bank dug away, I had the whole bed altered, and the bottom altered, and everything made exactly to specification; I had hand picked material, and everything done that was possible, and it was left to the perfect satisfaction of the maker, and the results were absolutely identical. I continued to experiment in this way with some large box filters—cubic yards—which I have been experimenting with. I started with only just a tap to deliver at the bottom and got several results, and after they had been going for some time I bored holes all along the bottom; the results were not altered in the least, although there was a possibility of free circulation of air throughout the filter. All these results have led me to think that the air is drawn down through the filter; and, moreover, in these box filters I have taken samples of air, and from the other filter I have taken samples of air from the interior of the filter, and I have always found plenty of oxygen. In Question 22828 I give some analyses.

22976. As regards that table you give us in reply to Question 22841, "construction cost per acre yard"—I do not quite understand what that means; does it mean an acre of 1 yard deep?—Yes.

22977. Well, then Question 22842, I do not know whether we might ask you a very general question. Supposing that you had to treat the sewage of a water-closet town of about 20,000 inhabitants, in which the sewage was an average domestic sewage, what other method of treatment would you consider most economical, supposing the Local Government Board would allow you to adopt any method you please for some time to come?—I think under those circumstances I should probably be inclined, in fact almost certainly, to adopt continous filters, but not necessarily sprinkling filters, because I think there are a number of objections to what are ordinarily known as sprinkling filters; but as matter of fact, I may say that I have at the present time a small scheme, not of quite such a size as you mentioned, which is at present being considered by the Local Government Board, where I have suggested continous filters of this controlled type. There again I should hesitate to give an absolutely general reply, because a good deal depends on the amount of attention that you can be certain of, and the precise result that you wish to get. Each case even there, even apart from levels, I think must be considered on its merits. There is no doubt of this, that apart from questions of economy, my experience has shown that, with double contact properly carried out you are almost certain to get a good effluent; I know that the Withington effluent, for instance, is one of the best on the watershed. I know that the Burnley effluent has always been good, not even fair; and I know that our own experiments showed that we never got by any exception a bad effluent from double contact; and, therefore for absolute certainty I think that double contact is the thing to be relied upon. On the other hand, if you can be certain of some supervision, and if you are concerned for economy in construction, apart from questions of pumping and levels, and so on, then possibly you may be wise to go in for a continuous filter.

22978. (*Sir William Ramsay.*) Have you any views on tanks?—In the same way would you submit a sewage to a particular tank treatment, chemical precipitation or subsidence?—I should in most cases give it tank treatment; which might be described as a rapid septic treatment, I should be very careful not to make my septic tanks too large; and the line I am going on is to design them for a 40 gallon per head flow and calculate the flow at 24 hours on a 40 gallon per head discharge; if it is more than that then the flow through will be more rapid; if it is less than that then it will stay in longer; of course, the sewage will be more concentrated.

22979. But do you call a twenty-four hours rest in the tank a rapid septic action?—Fairly so; I should be inclined to cut it down; that is the longest time that I should allow.

22980. (*Chairman.*) In the following Question, 22843, I am not quite sure whether you agree with the conclusion which seems to me to arise from your answer. It seems to me that the figures in the table you give go to show that a unit of material in one form of filter has just the same purifying effect as a unit in the other?—Within certain limits that is the conclusion I have come to.

22981. That is your conclusion?—I may elaborate it a little in this way, that speaking very generally, in the purification of sewage, I think of the two things, the nitrification of the ammonia and the gradual decomposition and the oxidation of the colloidal matter. Now, in order to oxidise that colloidal matter it seems to me that it must be first retained on the surface of the medium, and there it is simply and solely a question of surface one way or the other. The oxidation of the ammonia

on the other hand, although it is partly also a question of absorption, yet it is more a question of direct oxidation to nitrates. Nitrification is simply nitrification of ammonia, the nitrifying organisms have been repeatedly proved to only nitrify ammonia; therefore, in so far as in a percolating filter you have the rapid passage of the ammonia in solution under good conditions where you get good aeration, you do, as a matter of fact, get better nitrification as a rule in these percolating filters; these results here and other experiments that I have made show that also, but the really difficult matters, the colloidal matters, are it seems to me oxidized just in the same way in the two filters. It is just a question of the surface area and the air supply. I might perhaps be allowed to say that I was talking to Dr. Calmette of Lille the other day, who has gone into this question, and his final conclusion was that there is no such thing as a continuous filter, and there cannot be, because you cannot go on storing up this colloidal matter on your surface without allowing it an interval for complete aeration, for the oxidation to take place; and therefore, in any form of continuous filtration you may go on for a period, but when that period has elapsed and you have got up to the maximum that your bed will store, then you get bad filtrates at once, and you are bound to have intermittence; that is how I understood it.

22982. (*Colonel Harding.*) On this point, the observation of Dr. Calmette to which you refer surely must be wrong, is it not; he assumes there is a storage in the continuous filter of matter, and leaves out of consideration the fact that the matter comes out in the effluent?—I think you will agree that there is a storage, Colonel Harding, for a time at any rate. The point is that what goes into the filter at one moment may take many hours, or possibly days, or even years, before it finally gets out.

22983. That may be, but it does not necessarily follow that the action may not be continuous; one has heard of cases where it has gone on night and day for at least four years?—Absolutely?

22984. Without any rest or interruption except purely accidental, due to derangements of some of the machinery?—Then, of course, to push the point a little further, even with the sprinkling filter—it is perhaps rather paradoxical—but a sprinkling filter is that of intermittent, inasmuch as you are not putting the sewage on the same spot all the time.

22985. But that is a detail; it does not matter whether it is absolutely continuous or not; it is in effect continuous, there may be a certain intermittence in the upper layers of the filter, but there is an equalization lower down. But the point—Sir William Ramsay will excuse me interrupting his questions for a moment—the point raised seemed to be that the action of a percolating filter must necessarily at times be interrupted, in order to remove the accumulations of suspended matter within it; is not that the suggestion of Dr. Calmette?—That is what I gathered from what he said.

22986. The experience that we have found in various places is this, that suspended matter comes continually out of the filter, by no means in exact proportion to what goes on at a slow rate of flow; there is some accumulation which may have, at certain times, to be washed out by a more rapid flow, but which naturally comes out at different seasons of the year owing to the action of certain organisms?—But is that absolutely oxidised, that matter; do any of us know what that matter is that comes out in that way, and how long has that been in forming?

22987. It is very difficult to say, of course, how long it has been, but it is to a great extent oxidised?—Of course, I have been so much struck of late by the results at Accrington; when these filters first started there was only a very small amount of suspended matter coming out. Now, after five years, there is eleven grains per gallon of suspended solids, which are of such a nature that they have to be precipitated by allumino ferric at the outlet of the filter.

22988. I am anxious, of course, not to argue this point out, but so far as your own information goes with the small percolating filters that you yourself have tried, have you found absolute choking to arise if the material is fairly coarse?—No, not choking.

22989. Then you have found suspended matter come through?—With the coarse material, yes, quite so.

22990. Then surely the action may be continued indefinitely if there is no choking, if this comes through?—But the whole point is, is it not, the kind of filtrate, and by that I include the character of the suspended matter which comes through. I only want to get at it in this way, to find out what actually is the nature of the suspended matter that comes through. I can conceive that at first it is very fairly oxidised, but that if you go on and on you may get a fair amount of nitrification still, but that there are subtle changes in the character of the suspended matter that comes out; I am only asking for information, I am not stating facts now.

22991. That is not the point I wanted to get from you. What I wanted to get from you was whether in your own experience you found that if certain matters came out—I do not care what state they are in, whether fully or partially oxidised—it was possible to work a percolating filter for long periods without its getting absolutely choked?—Oh, that I can say without any doubt as regards the chokage; my thoughts were running on the character of the effluent.

22992. Then did I misunderstand your approval of Dr. Calmette's observation?—No; I am rather inclined to approve it from the point of view of the precise composition of what you get out of your filter including the suspended matter, if you want to get an absolutely thorough oxidation continuously. You can work your filter continuously merely as a mechanical operation, I have not any doubt; but what I understood from him, and where, I am bound to say, I rather agree—although this is one of the points on which I freely confess I have no accurate knowledge, it is one of the things I want to obtain more knowledge upon—but what my thoughts were turned to was this, that if you go on steadily in this way year after year that by degrees the suspended matter that you get out will not be so thoroughly harmless as it might have been at first, and that in order to continuously maintain a perfectly good effluent both as regards the matters in solution and the matters in suspension a certain amount of intermittence is necessary; that is how I understand Professor Calmette.

22993. And that is what you agree with from your own observation?—So far, although I must say that I am only learning; I am really only trying to get information on that point, but I am not convinced at present that you can go on for ever.

22994. (*Sir William Ramsay.*) In answer to Question 22803, I should like to ask if you know whether any experiments have ever been tried to find out the actual amount of oxygen which can be taken up by a unit area of a bed full of liquid. It would obviously be a very useful set of experiments to make but very difficult to carry out. You put in a certain amount of oxygen along with the water?—Very little. I do not attach much importance to the amount of oxygen which goes in with the water; in fact I may say that with our septic tank effluent I should imagine it was negligible.

22995. Then its first unit is only one: how much oxygen is taken up by that unit area?—That is another question: that is a whole research in itself which I want time and opportunity to go into; at present I am bound to say I have not got either.

22996. I was afraid you would say that. Then a little further down you say, "The superfluous bacterial growths will during this time be rapidly consumed, and the capacity of the bed will greatly increase. These rests should not exceed a fortnight at most, as the bed then tends to dry up and the activity of the organisms diminishes." Again, I should like to ask is that a matter of observation or probability?—Observation, to this extent, that if you wash out the material of the bed you get a brown humus-looking substance, which on rough drying is a quivering mass of jelly; if you allow it to go on oxidising in the air it breaks down, until it is simply granular earthy matter. Consequently it is obvious that that gelatinous material has oxidised; what I want to do when I have time and opportunity is to find out quantitatively how much of that is oxidised and what amount of carbonic acid is produced and nitrogen and so forth; that has never yet to my knowledge been done, and I am rather afraid that we shall find that the actual oxidation is less than is sometimes supposed.

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22997. Yes, you lay stress upon making the upper part of the beds of finer material than the body of the bed. Is that intended to keep back the fibrous matter?—The visible suspended matter.

22998. The visible suspended matter which can be easily removed afterwards, if I remember rightly from looking at your beds?—Oh, yes. Now, there again you raise the economic question; I am not absolutely convinced in my own mind yet whether it would not be wiser to let the whole of that go on to the beds; save your constant charges of scraping on the top, and spend a little more in occasional washing. All these things are matters of cost which only years of experience can actually tell.

22999. I suppose those top layers will contain nitrates in them, after being allowed to stand?—Oh, yes.

23000. To begin with they do not; they contain matter capable of giving nitrates but they do not themselves contain nitrates when they are removed?—Yes, just so.

23001. You scrape off the top layers which we have been talking about; these, of course, do not contain nitrates when they are fresh, but only after standing?—Well, standing a few hours.

23002. What do you mean by "very slowly," the beds should be worked very slowly; you are speaking of contact beds being started; I should like you to give numerical value to the words "very slowly"?—I think, as I have stated somewhere else "when we are beginning."

23003. That is what you refer to?—Only filling three times a week.

23004. (*Mr. Power.*) And on sustaining the contact?—Yes just so.

23005. (*Sir William Ramsay.*) I think it would be advisable if you would explain the meaning you attach to the word "streaming." You use it, and I think we understand what it means—running through continuously?—Yes; our storm beds, I may explain in detail, are especially constructed to enable that to be done at the outlet; we have the ordinary exit valve to drain the bed completely, and at right angles to that there is a bell-mouth. We can shut the exit valve, fill the bed, and let it pour out over that bell-mouth, and on occasion we stream the beds in that way, and of course when you have got a great deal of water down upon you, it saves labour.

23006. We have had evidence to show that that sort of process destroys the bed on the one hand, and does not help the storm effluent on the other, but at Manchester you appear to have pretty good results?—Because we do not let it go on beyond a certain amount; there will be sufficient stored nitrate in one of those beds to enable you to stream a very dilute effluent for a certain time; then you must stop, and you have to watch that to see just how long you can go on. If you go beyond that, immediately you will have anaërobic conditions probably.

23007. It is a considerable time since we visited your works; as far as I remember the streaming beds were separate from the filtration beds?—That is so, yes.

23008. Are they still separate?—Oh, yes.

23009. You do not use the streaming beds except during the storm overflow?—That is all, and only at the end of the storm. I think in one of these answers I say "there are special instructions given, that at first they shall give full contact, if possible."

23010. Are they lying vacant, doing nothing?—Yes.

23011. (*Mr. Power.*) Do you not use them—give them a dose now and again?—Yes, we fill them about once a day, because we have to bear this in mind, that there is no possibility of second contact there, therefore anything that goes into the canal has to be purified, and after one contact we do get, as a matter of fact, a very decent effluent.

23012. (*Sir William Ramsay.*) So they are always kept in working order?—That is so.

23013. In answer to Question 22819, you give results to show that with the same liquid the purification increases directly with the fineness of the material; but would it not also increase with the time?—I do not think so.

23014. You do not think it matters at what rate the percolation takes place; you are speaking of percolation filters?—Of course, here the experiment was merely to determine the effect of the material; therefore you must keep all your other factors the same.

23015. And that was done; the rate was the same?—The rate is given here, but you will find here, in the worst case, we put on the least amount, so that we are really giving something in there.

23016. I am afraid I do not see where the rate is?—The average amount dealt with per cubic yard.

23017. Oh, I see, in the given time?—Yes, put there; "per day" I ought to have said; perhaps I had better put that now.

23018. I think it would be better; the rate of passage indeed would be the best heading. In answer to Question 22822, would you mind saying what experiments showed you that the same results could be obtained from the two filters, one fed by an expensive distributor, the other by a fine top layer; perhaps you would rather not mention the names?—I do not think it is desirable to mention the name of the distributor, but at the same time the experment was briefly this. I had two cubic yards of filtering material of exactly the same description, and fed, as I said before, with exactly the same effluent, a measured quantity from the box above, and the whole of that effluent taken in a box below; and the only difference was that in the one case I just covered a portion of the surface, made a sort of little basin of fine material, and in the other case there was the distributor. I have had other cases which lead to the same conclusion, I may say.

23019. Would it be possible for you to say something about the size of the material used in those percolating filters?—It is given, I think, in the answer to Question 22819, but I can put it in again if you like.

23020. Just the same? Yes, I see it is the same?—The two were absolutely identical. Perhaps, as you have just got to that Question 22828, I see I have given no answer to Question 22829: "What do you consider is the most convenient superficial area for a percolating filter?" I think it would be possible to say that that area should be such a fraction of the total area that if it is thrown out of work it will not interfere with the general treatment. I have heard of cases where the whole of the sewage has been put on to one bed, and if anything goes wrong of course the whole work is stopped.

23021. I do not know whether you know that Dr. McGowan has been carrying out some experiments with Ducat's filter as regards aeration?—I did not know that.

23022. And he has found that when the sides are stopped up there is a very great difference in the amount of oxidation which takes place. That looks as if the sides played a more important part than from one or two of the answers one would imagine?—But is not the surface of the Ducat filter rather fine material, if I recollect aright?

23023. Yes, it is rather fine material?—Just so.

23024. It ponds, as a matter of fact, at the top?—Well, that is what I was trying to arrive at. In our case you see you had no possibility of the air getting in by the side, so that I thought it came in from the top.

23025. (*Dr. McGowan.*) So it does; that is our experience; it comes from the top downwards?—Oh, yes.

23026. The experiments are not concluded yet. You see that Ducat filter treats sewage containing about 20 parts of suspended solids per 100,000. It has been suggested by Mr. Fioris that when the side pipes of the filter are closed, and no air can escape through them outwards, the passage of the solids through the filter is impeded and they therefore tend to settle. After the side pipes had been closed for a comparatively short time—some six weeks—ponding took place over the surface of the filter. The experiment is not concluded yet, but it looks to me as if that answer of yours on the question of side aeration might possibly have to be modified, taking the amount of the suspended solids as a factor?—That is to say, if it cannot get in at the top it may get in by the sides.

23027. (*Sir William Ramsay.*) Yes?—I shall quite agree to that, but all that I meant by my answer was that if it has freedom it will naturally come in from the top, and the side aeration is of little importance.

23028. A question arises from your answer to Question 22840; is it conceivable that any disease could be propagated by those flies?—Well, I am not competent to give medical evidence.

23029. I admit that, but nothing of that kind has ever come your way, has it—with, for instance, people who live on the sewage farm?—No, we have no flies. Well, I do not know whether I have not heard of it, but still the general trend—speaking simply as a layman in this respect—the general trend of research surely is to point to flies being a very serious cause of transmission of disease.

23030. It occurred to me it might be serious?—I am bound to admit that the flies which I saw on the percolating filters in Berlin were extremely unpleasant.

23031. Dr. McGowan wants me to ask you about your answer to Question 22851. Why do you mix the volume in the sample with nine volumes of aerated tap water; why nine in particular?—Originally it was done in order to compare our results with those in the Mersey and Irwell Joint Committee's laboratory, and also to ensure that we had a good access of oxygen, enough to oxidise everything.

23032. As regards standards you say you do not think that one standard should be adopted for all non-potable streams. Of course you would guard that again by saying it depends upon the size of the stream, the nature of the effluent, and the rate of the stream?—Crowds of things.

23033. Whether fish are required to live in the stream, and so on?—Yes.

23034. Is there any way you could suggest how this difficulty could be got over. Of course there is the Mersey and Irwell standard, which is a very lax one, but one feels that in very many cases it is not nearly tight enough; it might be made very much better—more stringent?—I am afraid the Lancashire people would not like to hear that.

23035. But for potable waters you would grant that it is too lax?—For potable waters I would not allow, surely.

23036. If fish are allowed to live in the stream again?—There it would depend solely on the size of the stream.

23037. I fancy you would agree with this view—that if some sort of regulations were made like those which the Alkali Act prescribes, a great deal of latitude being given to the inspectors, and some standard laid down, a very lax one, the proviso being that the inspectors should receive instructions to try to tighten, to make the standard more stringent, that their common sense could be trusted gradually to bring about an improvement. You know the recommendation in one of the former reports has been that there should be a central board, that there should be also a number of rivers boards; these rivers boards will be furnished with inspectors; should they be given some power like the inspectors under the Alkali Acts have, by which they could gradually increase the stringency without interfering with the liberties of the manufacturers or of the towns in disposing of their sewage?—I think that is a very reasonable suggestion; in fact, I have rather hinted at something of the kind, I think, before. I think we had some question of that the last time I was before the Commission, and in one of my answers of Question 22858, I have gone into that question a little, and I certainly think that standards should be more for the purposes of comparison, and for encouraging emulation amongst authorities than as instruments of rigid control. That is briefly my position on the question of standards.

23038. Just one other question: Do you think the same inspectors could deal with the question of water supply?—I think so. I might, perhaps, be allowed to say that I have recently been to the Government experimental station in Berlin. I think I have mentioned that. "My recent visit to the Government experimental station at Berlin has impressed me afresh with the great importance of the formation of a central authority." I may say, although I dare say I am not giving any news to the Commission in this respect, that both my companion and I were very much impressed by the work that they are doing over there. There were some fifty members on the staff; engineers, chemists, biologists, bacteriologists, every kind of profession which could in any way help in matters of sewage and water supply—the two are taken together—and practically no town in Germany now is encouraged to enter into expensive works for sewage treatment until they have had a thorough report by the officers of this Government station. We went to Cassel in order to inquire into the fat extraction process there, and we found that an official from the Berlin station was going down that day to thoroughly examine into it, and give a final report on the question, and until he had done so, no definite steps would be taken by the town, or anyone concerned. In that way the town have an opportunity of the very best advice possible on every question; at the same time they can themselves help in all the preliminary inquiries. That has been done in several cases. In the case of the town of Hanau the question arose as to whether sewage should be allowed into the river after the adoption of water-closets, and a large amount of evidence was collected by the officials of the town, and supplemented by a final report from Berlin, and that is the way the matter is being dealt with throughout Prussia, at any rate.

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23039. The Berlin office I presume is a Government office?—A Government office.

23040. Not a municipal one in any sense?—No.

23041. (*Colonel Harding*). Dr. Fowler has answered his questions so fully that it is only on one or two points that I want to ask a few questions. On the question of volume of sewage at Manchester, I notice you say the maximum amount—reaching the works—in twenty-four hours, is 163,000,000 gallons?—Yes.

23042. That is really about six times the dry-weather flow, quite roughly?—Yes, six times the actual dry-weather flow; more than six times what I call the strict dry-weather flow.

23043. But roughly, six times. Now, may one take it that that is the capacity of your mains?—Oh, we can get more than that down, because if you look at the next question, I think, or the question just above, the maximum rate was 220,000,000.

23044. For a short time?—For a short time, and if that went on all day you see we could get on still more.

23045. Then probably that is what may come up to the point of the overflows?—Yes.

23046. You tell us that the total amount that has come to the works in a year is 12,000,000,000 gallons?—Yes.

23047. And that is about forty per cent. more than the total volume of the dry-weather flow for the year?—Yes.

23048. I find that your dry-weather flow figure, reckoned out for the year, works out at about 9,500,000,000 gallons?—Yes.

23049. So that the thirteen would be nearly half as much more?—Yes, that is what I have taken.

23050. I note those figures with some interest, because I want to get at this. If an authority deals with six times its dry-weather flow, what may that be taken to represent in volume compared to the dry-weather flow volume alone. For instance, if the total dry-weather flow for the year be 100, what does it mean to treat six volumes; does it mean treating 150?—I have always taken it as meaning that; in roughly calculating out what an authority would have to deal with, I have always taken their dry-weather flow and added fifty per cent. more for storm water.

23051. That is the point I wanted to get at: I wanted to know what in your opinion that volume would be. It is exceedingly difficult to get the information which could I suppose, be got by a careful examination of the rain records and so on?—It would, of course, always vary according to the inclination of the sewers, and so on; but speaking very generally, and with my experience, from what I know of Withington sewage and other places that I have watched, I think it is a safe thing to say that if you take the six-times limit you will get 50 per cent. more to deal with.

23052. That was the point upon which I wanted to get your opinion?—I can say that with some confidence.

23053. To what extent may the water supply of a town be taken as the measure of the volume of sewage?—I think it is a very good measure provided that you also take into account any other sources in the way of wells, and so on, which may exist—large breweries, for instance, often

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have their own wells. That is manifestly the volume of sewage; anything beyond that, any question of subsoil water, is dilution.

23054. I am rather struck with the difference of Manchester; I notice that the gallons per head of sewage, reckoned on your population, was forty-six; taking your dry-weather flow and dividing it by the population, it gives you forty-six gallons a head of sewage?—Yes.

23055. And that your water supply, including what is used for trade purposes, is only twenty-nine?—Yes, the balance is subsoil.

23056. Would it be so much as the difference between forty-six and twenty-nine?—There is this average of 6,000,000, you see, on a strict dry-weather flow of twenty-one.

23057. In many cases I have found that the water supply is a rough measure of the amount of sewage produced, but I am rather struck with the difference at Manchester—forty-six to twenty-nine?—There is a great difference, and we went into that question very carefully; General Carey knows the detail of that very well. That was the basis upon which our scheme was devised. We took, if you will remember, General Carey, for Manchester the dry-weather flow as calculated by the water supply; we added a certain percentage for private sources and so on, and we took our six times as six times that; we left out of account, you remember, the 6,000,000 gallons of subsoil water.

23058. (*Major-General Carey.*) Quite so. On that point perhaps I might ask Dr. Fowler as to the total dry weather flow, how it is made up; the dry-weather flow on the water supply proper comes to about 9,200,000 gallons at sixteen gallons a head?—Pardon me, the water supply is more than that; do you mean leaving out of account trade waste?

23059. If you take your answer to Question 22714, your water supply totals up to twenty-nine gallons?—Twenty-nine gallons.

23060. That is at sixteen gallons a head for the domestic supply?—Yes.

23061. That works out to 9,200,000?—Just so.

23062. In addition to that you have 7,475,000 of trade water?—Yes.

23063. That totals ap to 16,675,000?—Yes.

23064. And if you add to that 6,000,000 of subsoil of water it makes 22,675,000; there is a certain difference between that total and your total dry-weather flow of 25,000,000?—There is the difference between twenty-two and twenty-five.

23065. And twenty-five, yes?—We took as the strict basis 21,000,000, and that included extraneous water of various sorts, from wells and suchlike.

23066. Just so; that is exactly what I wanted to know——

23067. (*Colonel Harding.*) And you think that is the explanation of the great discrepancy between the two sets of figures?—Oh I do, undoubtedly.

23068. That in Manchester there is much independent water supply?—I know of certain breweries which have their own wells.

23069. You really think that it is of sufficient importance to account for the great discrepancy between the two sets of figures?—I know of no other way of accounting for it; of course this figure of 6,000,000, is, after all, an approximation.

23070. (*Major-General Carey.*) It may be an under-estimate?—It may be an under-estimate, and it is an estimate, moreover, which I think one of the answers shows varies at different periods of the year In a rainy period you will have much more subsoil water than at another period, and it will continue after a period of rain for a long time; there are certain parts of Manchester I know which are simply full of subsoil water; the drains are laid near canals and so forth.

23071. (*Colonel Harding.*) Proceeding then with the question of dealing with a certain number of dilutions of storm water, we are much interested in your evidence because you have had opportunities at Manchester of trying actual experiments upon storm beds concerning which you have given us valuable information. Do you say that those beds act very much like the sand beds at Watermouth and Bath. I suppose you mean to convey to us that you think their action is more mechanical than chemical, unless you except the storage of nitrate during the times of rest?—Yes, I think I would say so. What was in my mind was that the fine material acts mechanically in retaining the fine particles.

23072. Just as sand filters do for waterworks?—Yes, precisely; it is really a coarse waterworks filter; and we find further, as I have stated in one of these answers, that you get your best results when the whole surface is covered. If the bed is very loose, and the water drops immediately into the under-drains and fills up, you do not get such a good filtrate.

23073. In streaming through such a filter, you are getting results which are largely mechanical results?—Largely so.

23074. But the chemical results are due almost entirely, are they not, to the nitrates which may have been stored in the filter during times of rest?—To be sure, and that has always been the principle upon which I looked forward to dealing with storm water, because I foresaw that it was impossible to make your works of such a size that from the mere point of view of engineering you could deal with it; but if you had a certain area which was in a high state of efficiency owing to the long rest periods, then for a short time that area would be able to cope relatively with more than it otherwise would.

23075. Let me put it in this way. Were those storm filters used as streaming filters continuously, it is quite evident their action would be merely mechanical?—That undoubtedly would be so.

23076. And it is merely the intermittence of their action which allows of the storage of nitrates which makes their action somewhat chemical, the action being mainly mechanical?—Yes.

23077. It would not be possible on such storm filters to deal with storm waters which had not been previously settled?—I do not think so. I feel that; I think I can answer that pretty directly; I do not think you can—not satisfactorily.

23078. Can you pass crude storm waters on to such a storm bed as you have at Manchester?—Not satisfactorily. As a matter of fact I have had rather an interesting experience on that very point at Withington, where no tankage was allowed, and I found we were having such a struggle in getting deposits off the top of the beds, and we got rather foul effluents, that I have converted some old experimental contact beds into settling tanks, and we pass the sewage through these before it gets on to those beds. I think as a matter simply of practical politics some amount of settlement at any rate should be resorted to—for this reason: that if you have your storm beds of very coarse material, you will get practically no result; the sewage will simply stream through and come out at the bottom very much as it went on. If, on the other hand, you have them fine enough to get a result, then, unless you have settling tanks, you will block the surface with the first rush of stuff you put on.

23079. You have made that quite clear; to get a storm filter to be effective it must be fine, and if it is fine you must previously settle a large part of the suspended matter?—That is certainly my opinion.

23080. Are you able to tell us from memory, or by any figures before you, what is on the average the amount of suspended matter which you are able to settle off by those storm filters?—I do not know that I can speak more than from my general knowledge, but I should think we have sent, without doing any damage, at times, effluents containing as much as probably 12 or perhaps 20 parts.

23081. As a maximum?—As a maximum; I do not think more than that.

23082. But you would prefer the 12 to the 20?—Certainly, you may put it in this way, you have a big storm rush with perhaps 100 grains per gallon rushing through your settlement tanks and you will get out 80 per cent; that gives you your 20 grains.

23083. If it were possible to much more completely clarify storm waters the filtration would become quite easy?—Oh yes.

23084. Either through contact or percolation beds ?—Yes; the more you spend on tanks the easier is your subsequent treatment. I think perhaps before leaving that point I should like to say that one trouble that we have with these beds, and in fact with our beds generally, is that of grease, because in all works there is a considerable amount of grease, and a rush of sewage often brings this past the skimming boards and on to your beds and it is more the grease contained in the suspended matter, and the grease actually floating on the surface, that is apt to clog the bed than the actual granular suspended matter. We are taking steps now, in fact that is the reason of my recent visit to Germany, to find out the best way of coping with this difficulty.

23085. To pass on to the question of septic tanks, I am interested to see that you are firmly of opinion that it is advisable to frequently remove a small quantity of sludge from septic tanks with the idea of maintaining something like constant capacity in septic tanks. You said something about the necessity of working septic tanks in a series so that there should be a first and last compartment besides the main central compartment ?—Yes.

23086. And if I remember rightly, in some former evidence you gave before us, you said that the object of having this last compartment was by the frequent removal of the sludge formed in it to be able to reduce the amount of suspended matter coming away with the effluent ?—Yes.

23087. Will you tell us how far your experiments have justified your hopes in that direction ?—We have had a long experience in trying to solve that difficulty and I think at last we are enabled to do so, because I have found, as a general thing without any doubt, that the quantity of suspended matter which passes away is chiefly dependent on the quantity of sludge in the tank; that if you keep your sludge down at the exit, to a certain minimum depth then you will not get any very large amount of suspended matter going over. You can always keep it to the economic limit of eight grains, but in order to keep your sludge down to that limit, you have to frequently take out a small amount, and we have found it is quite easy to take it out from the inlet end by having a submerged wall provided with penstocks from which the sludge can be forced by the pressure of the water. The difficulty was at the far end, but after trials of numerous methods, we seem to be at any rate on the point of success. I do not like to speak too confidently, but so far as we have gone, the thing seems to work by having a series of manholes built on to the bottom of the tank, and provided with radiating arms which cover a large surface of the tank underneath the sludge, and by opening one of these arms after another, the pressure of the water forces the sludge through and back down the pipe, and we find we have got a very large amount of sludge in that way in that very simple manner. Of course this is Mr. Wilkinson's device, he will be able to tell you a little more about it, but I have seen a design in his office for making these manholes very neatly and simply so that they do not take up much space in the tank, by making them practically all of iron with just a sufficient base to be attached to these distributing tubes. In that way you get the advantage of the circular tank which is used in order to drive the sludge out from the bottom without the disadvantage that in such a form of tank you get both digested and undigested sludge coming out at once; here in a rectangular tank you get the two things separate.

23088. (*Mr. Power.*) You get the bottom layer throughout ?—You get the far end and the near end.

23089. (*Colonel Harding.*) I was anxious to get your view upon that point because you agree with me that the reduction of suspended matter in a septic tank effluent is the great problem we have to solve if purification of the septic tank effluent is to be effectively carried out. What the economic limit would be would depend, I take it, on your different works. If you have a very small area for filters then you will have to go further in reducing the amount of suspended matter that you allow to go on to them ?—I think I have said that in my evidence in comparing Manchester and Salford.

23090. You have shown at Manchester that you are able to deal with a certain quantity of suspended matter, I think about eleven grains per gallon is it not ?—Well, we have found that eight is about right; eleven parts per 100,000.

23091. You are able to deal with that practically; on the Manchester filters, it is kept mainly on the surface; there is no doubt some digestion of the matter and what remains there in a condition of humus is scraped off ?—To a large extent. You see anything that is on the surface is dried and practically all the labour consists in removing it.

23092. So that there can be no direct answer to the question what is best to be done in regard to the extent to which you should separate out suspended matter. It must be dependent on local circumstances to a very great extent indeed ?—I think so.

23093. In some cases it may be better to settle almost everything out of the sewage and filter clarified sewage; in other cases where the disposal of sludge is extremely difficult, then you must settle less and deal with more upon the filters ?—That is my point exactly.

23094. I was interested with your suggestion that there may be cases where it is better not to settle at all, but to endeavour to deal with all the suspended matter in sewage aerobically ?—I feel certain that that is the case. Of course you are yourself well aware of the Leeds experiments which I think were most interesting.

23095. At Leeds the experiment was carried out on percolating beds, and certainly if that should prove to be practicable, it would be a method of treatment least likely to give rise to nuisance ?—I think it is an excellent method.

23096. My object in just referring to it was to ask you how far you thought it was possible to carry out a process of that kind on contact beds ?—I am hoping to have more information on that point before so very long. I feel confident from what I have seen at other places, for instance at Hampton, that the thing can be done, because it is all a question of the cost of cleaning up material, and that has been proved to be capable of being done at a very reasonable cost. But of course a method has been suggested recently, as you are probably aware, by Mr. Dibdin, of using more expensive material, of using slates in fact, slate chippings which will enable this stuff to be flushed out *in situ*. I am bound to say I am rather interested in that suggestion, and I hope to have some experimental knowledge of it before so very long.

23097. There is a slate filter on trial at the present moment at Leeds; I do not know whether you have seen it ?—I saw it, but it was being tried as a continuous filter, and for that purpose I do not think it is well suited.

23098. It is most ineffective for the purpose, but it has since been changed into a contact filter and in rearranging the material it was found that all the lower portions of the slate were broken up, and that that kind of slate at least is unable to bear the weight except at a very shallow depth of material.

23099. (*Sir William Ramsay.*) There were regular slabs of slate built all together ?—That is how the thing is designed. I think that something more might be done in the way in which it is put, in fact in some correspondence I think I suggested that by modifying, by carefully arranging the slates, you could get it, that by simply opening a small portion of the filter you could expose the whole of the material and sluice it all down if necessary; but I hope to be able to try the thing in a small way at Withington, where we are faced with the sludge difficulty in a much more serious form.

23100. (*Colonel Harding.*) The suggestion that it may be possible to deal upon filters, contact or percolating, with screened crude sewage, is one of very much interest, and I think well worth investigation. You have referred to the possibility of the use of slates which will enable such a contact bed to be washed out ?—That is so.

23101. It may interest you to know that at Leeds we have suggested spherical material of hard burnt brick, and that there they are just now trying an experiment with such material; and the special feature of the material is that all the air spaces would be alike ?—To be sure.

23102. And that it would probably be quite possible to wash out a contact bed so constructed ?—I saw the material when I was over in Leeds; I think it is a very good idea.

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23103. In the first instance the idea there was to use it for percolating filtration, for which it would be very suitable, but what you have said just now leads me to point out that it might enable a contact filter to be cleared of matter which had been changed, oxidised to the condition of humus?—Yes.

23104. And it would be important, would it not, to note the difference between material which is passed through a filter like that and settled afterwards and material which is settled before filtration?—Certainly; it is just on that question that I feel very strongly we all want to know a great deal more.

23105. We shall want settlement some time?—Certainly.

23106. But the suggestion of treating crude sewage on filters is interesting, because the settlement afterwards will mean the settlement practically of oxidysed matter?—I hope so.

23107 Your experience with contact beds at Manchester of course has now extended over some time and is undoubtedly on a large scale, and we are very anxious to get certain information from you. I have not gathered from what you have said in your answers to the questions, that you have yet reached the necessity at Manchester in connection with your large beds—either to change the material or wash the material?—No; there is perhaps one bed which we are at present a little anxious about; it is in its 5th year. My estimates were founded on five years life. Only this morning I got from my assistant the capacity measurements of the bed 1a, to which reference has been made before, and it still shows a very good figure. That is the oldest bed we have got.

23108. These are the practical points upon which I want you to be good enough to give us your opinion from your large experience at Manchester. How far is it practicable and economical to reduce the capacity of a contact bed. Clearly a contact bed will go on passing sewage in reducing quantities until at last you reach minute quantities?—Oh yes.

23109. And that will last a great many years, but what is the economical limit, I mean the proportion of capacity to which you think that contact beds may be reduced?—I think that one might put it perhaps in this way that the capacity should not be so reduced that the whole volume of the sewage cannot be dealt with in a reasonable way. Manifestly when the bed is new, in order to cope with the whole of your sewage, you will have to fill it perhaps once or at most twice a day; as time goes on, you will find the labour of opening and shutting your sluices increasing.

23110. Then in laying down an installation, the area must not be calculated upon what will be first passed?—Oh no, no.

23111. You must consider what will be passed when the beds have been working a considerable period?—Your calculation should be based on what is practical to be done in the number of fillings per day when your bed has reached its ultimate capacity.

23112. You have said quite properly when you reach the point that you have not contact beds enough to deal with your sewage, you must then increase their capacity by washing them out or by introducing new materials?—Certainly.

23113. In laying out a scheme, what do you think is the reduction of capacity which is economically and practically to be looked forward to?—I think you may look forward to a capacity of somewhere between 17 and 20 per cent.

23114. Of what?—Of the empty tank capacity. I may put it in this way. I have often made the calculation in my own mind; from our experimental beds we found that these experimental beds went on for so many years, the A.B.C. beds got almost constant for several years at 18 or 20 per cent., and that meant to something like 200,000—I am speaking from memory—I think it was 200,000 gallons per filling per acre, 20 per cent., 150,000 is one-third; 150,000 gallons is the one-third capacity of a half acre bed, that is to say one filling per acre at one-third capacity is 300,000 gallons. That is to say, in order to cope with half a million gallons per acre, which is what the works were designed to do on the whole, you would have to fill that bed once and a half per day. Now, when you get down to 20 per cent. your filling per acre will be 200,000 gallons, therefore you will have to fill it on the average two and a half times per day and that is quite practicable. That is the average you see. In time of storm, you will have to fill it twice as often perhaps, that is to say about five times per day. Now five times per day is the limit that we have told our workmen they are not to go beyond; they are not under any circumstances to fill those beds more than five times per day. If the capacity I might say gets down to such a point as in order to cope with the flow you must fill your bed more than five times per day, then the time has come to do something to that bed, because more than five fillings per day will not give you adequate aeration. I do not know if I have made myself clear?

23115. I am very anxious to condense the interesting information which you have given us if possible. Your original water capacity at Manchester would probably be about 45 per cent. of the cubic capacity of the tank?—That is about it.

23116. Then down to what figure do you consider it is practicable to reduce that capacity; down to the figure 20?—Down to 20 certainly.

23117. Putting it in that way I shall be expressing your views?—Oh yes; 20 is quite practicable.

23118. We have reached that. Now I want to know, from the experience you have already attained at Manchester, how many years do you think it would be possible, in your conditions at Manchester, to work the contact beds before you reach the limit to which you have just referred?—We have worked them as matter of fact well into the fifth year. How long more will they go is a matter of experience. I should say they will go one, possibly two, years more with care, but our oldest bed is in its fifth year. We have had an experimental bed going six years at an average rate of half a million gallons all the time, and I made my estimates for renewal on a basis of five years.

23119. The actual life of the beds, as tested by practice, is evidently a little greater than what you had anticipated?—Yes.

23120. And when the time comes, you do not consider that the cost of washing them out will be prohibitive?—No.

23121. I notice in your answers you quote the cost at Burnley?—Yes.

23122. You do not express any opinion I think as to whether you think that cost is one which is likely to be exceeded or otherwise at Manchester?—I do not see how it can be, because we can do it certainly more cheaply than they can by doing it on a bigger scale. Of course I have gone very carefully into that question. I may say I have got an estimate for doing the whole lot by contract for 1s. 6d. In making my estimate of the probable cost, I put it down at 2s. per yard, so as to be perfectly safe, and it was still financially possible.

23123. That opinion of course is a very important one. It is necessary to remember that the cost of 1s. per cubic yard is not the whole cost, because there is involved, is there not, some washing away for the broken down material, therefore there will have to be an addition of new material to make up for that?—That is so to some extent. In my estimates I may say that I calculated that in, so that, as I say, I have not based my estimates on 1s. a yard in giving them to my Committee.

23124. But you have taken into account that some of that material will be washed away and is undesirable to be put back at all, and that you will have to make up with new material?—To this extent; but you have also to remember this, that a good deal of that broken down material can probably be used in other ways; not the very finest, but for instance, we are at present contemplating the construction of a number of second contact beds, and the material which is still sizeable, if one might say, which is not simply slurry, would make excellent material for these second contact beds, and therefore to that extent is an asset. And that is how they are doing also, of course, at Burnley. And apart from that the material which we put back in the primary bed occupies almost the same space as the material we took out, because it

is so much looser to begin with. I have made special experiments on that line, and I find that although we have a loss in weight the stuff occupies very nearly the same space.

23125. The practical point I wanted your opinion upon, was whether you consider it economically practicable to wash beds, and I gather that you do ?—I do.

23126. And you think that the length of life of a contact bed, working on the conditions of Manchester, will be sufficiently long to permit the using of contact beds economically ?—I may say I am sure of it.

23127. Of course their life would be lengthened by more thorough sedimentation, but in your case you consider it is economically better to deal with part of the suspended matter on the contact beds themselves ?—I think so. That is a point upon which I am at present not certain as to how far the mere removal of the suspended matter to a greater extent would, in our case at any rate, so greatly increase the life of the bed, because, amongst various causes which produce the loss of capacity, the suspended matter is only one, and that not in my view altogether the most important.

23128. No doubt you are quite right that there are other causes at work, such as disintegration and consolidation ?—Exactly.

23129. There is a point in connection with sludge upon which I should like to have your opinion. You have said that, in your case, the farmers will take the sludge in small quantities?—In small quantities at certain times of the year.

23130. As a fact it is not necessary for you to press it on the farmers, because you are able to send it to sea ?—Yes.

23131. You have the good fortune there to have an issue out of all your difficulties ?—I may say that at this present moment I am advising a return to pressing as regards part of the sludge, for this reason, that although we are producing less sludge, our costs are not reduced in proportion, and in that way we do not get the advantage which we should get of the use of our beds as to some extent sludge destroyers, and, in order to get that advantage, we have entered into an agreement with Salford to remove their sludge as well and lay up their steamer. With only one steamer we cannot entirely cope with the whole of the sludge, but by pressing a certain proportion of ours and taking the rest to sea, we then bring our sludge cost more in proportion to our actual sludge production.

23132. I hope you will be successful in reducing the cost. But the point that I wanted to get information upon was in relation to authorities that are not able to send their sludge to sea at all. If the sludge does not commend itself to the farmers of the neighbourhood, and if they cannot send it to sea, what other methods are there of disposing of the sludge ? One method has been suggested to us, and it is that particular method that I want your opinion upon. Is it practicable to burn sludge cake without producing a nuisance and within reasonable limits of cost. Have you any experience ?—Well, we have tried to burn a little in our destructor, with no very great success I am bound to admit, and of course I am familiar with other places which have tried it. There is great danger of a lot of dust difficulties and cost of various sorts. You can get evidence of course on that particular point from others better than from me. For instance, at the Bolton works they can tell you a good deal upon that point.

23133. I think it was from Burnley that evidence was given to us that sludge was burned ?—At Burnley they send it away.

23134. Huddersfield ?—At Huddersfield they have done a good deal.

23135. And we were told that there was no nuisance from it. Shall I be right in taking the amount of water in cake at about 50 per cent. ?—Yes, that is about right.

23136. And it costs a good deal to evaporate that ?—Yes; and then you have a great deal of mineral residue.

23137. I do not press you on the question of percolating filters at Manchester, because you tell us that your experience at Manchester has been limited to certain experimental beds, and that you have not carried out works on a large scale ?—No.

23138. And in reference to other places, that you probably got the evidence direct from them ?—Certainly.

23139. About trade effluents; something was said to you by Sir William Ramsay about the amount of iron liquor. I was rather surprised to find that in the classified list you gave us I did not find iron liquor occupying a separate place; is it included in one of the others ?—I think it is there, is it not.

23140. Is it included under galvanising ?—Yes, that is the iron liquor from galvanising; it is included under that.

23141. That would be ferrous sulphates and ferrous chlorides ?—Mostly ferrous chlorides; or almost entirely. They treat the iron wire; it is mostly from wire works, galvanised iron wire; they treat it with hydrochloric acid.

23142. Briefly, in regard to trade effluents, what you find is that although certain trade effluents delay the maturing of your filters and take up oxygen which otherwise would be useful in oxydising organic matter, you have no great trouble if the flow is a regular one spread over twenty-four hours ?—We have a trouble, a serious trouble of course in coming within the limits of the oxygen test of the Mersey and Irwell Joint Committee, not in producing a non-putrefactive effluent so much, but of course we have that much more permanganate taken up throughout our works. We start with ten grains, or ten parts per 100,000 and we have to bring it down to one and a half.

23143. (*Sir William Ramsay.*) That is a case where the standards might be altered ?—Well of course that is what we think.

23144. (*Colonel Harding.*) No one suggests that the trade effluents assist you; they are a trial and a trouble in a way, but you can deal with them supposing they do not come in rushes ?—Yes.

23145. And your Corporation considers it is good policy to receive them ?—Oh yes.

23146. (*Mr. Stafford.*) I was interested in what you said about the German Government setting up a Central Authority in Berlin for dealing with sewage effluents. Do you think that with regard to these matters their investigations are more thorough than what is done over here by the English Local Government Board?—I think so, because you see they institute very careful experiments of their own. For instance, one question that was being discussed when I was there, was the treatment of the effluents from these huge colour works on the Rhine. They are working themselves and experimenting in the Laboratory and overlooking experiments by the manufacturers, and at present the matter stands that there is no way of dealing with them.

23147. Do they charge a fee, do you know, the German Government ?—Oh yes.

23148. For this advisory work?—For any analyses that are made, and I imagine they charge a fee for their report as well. Oh yes, I have got a list of fees they charge for analyses, but I do not know what they charge for reports.

23149. (*Sir William Ramsay.*) Is it compulsory that the town should employ the Government experts ?—I do not think it is compulsory, but as a matter of fact they do.

23150. Because it would be rather a curious situation if the Government insisted upon their being employed and at the same time charged them a fee ?—Of course, naturally, one has to take into account the difference between the German and the English temperament.

23151. (*Major General Carey.*) In answer to Question 22770, you mention some advantages of the covered septic tanks, "On the other hand, wind and rain have a disturbing effect on an open tank, and tend to break up the scum and allow pieces of it to pass away in the effluents. A closed tank is more sightly, and, where complaints of smell are likely to arise, is desirable." Is there not a certain element of danger in the closed septic tanks owing to the confined gases against which certain precautions may have to be taken ?—I think with reasonable care there need be no danger. Of course I am bound to admit that accidents have occurred and also that in certain cases it is a wonder that more have not occurred.

Mr. Gilbert J. Fowler, D.Sc., F.I.C.

12 May 1905.

23152. Very serious accidents I think, occasionally?—I have known them, but I think with reasonable precautions it ought to be all right. Of course if you had an assistant, as in a case I know of, who put a light at the top of it, and airily told the surveyor that he had got a flame about two feet high, it is a different matter. We were all rather pleased that nothing worse had occurred.

23153. I think the tank at Cromer was blown up owing to some want of proper care in bringing a light in. Now, Question 22801, as to this proportion of cubic yards of filtering material per head of population; that is a very interesting one to me and I think an extremely useful one to the Local Government Board, if it is correct. Does that proportion provide for the treatment of storm sewage as as well as the dry weather flow per diem?—Yes.

23154. And also allows a margin of occasional rest to the beds?—Yes. I got at it, I may say briefly, simply by counting up what would be required after a complete double contact at Manchester and what is as a matter of fact provided at Burnley where they get a perfect effluent.

23155. It works out roughly at that?—It works out roughly at that at Manchester, after a complete double contact for a first rate effluent.

23156. Including the storm water?—Yes.

23157. And works out near enough to be accepted as a unit?—If you want to be safe I think that is a figure to take. It is what I am taking myself, though I am bound to say sometimes you have to cut under it.

23158. As regards percolating filters, I understand you have not made any experiments with filters over six feet in depth—percolating filters?—I have one going in a small way at the gas works in Manchester, endeavouring to oxidise this ammonia recovery liquor; I have got one twelve feet deep and I am getting rather good results out of it.

23159. You have not got any record of your results?—Not yet.

23160. In your table of comparison, Question 22819, you only refer to six foot percolating filters?—That is as far as we went.

23161. Question 22841, in the table you give "renewal cost per acre yard per annum"; is that per acre yard deep or what is per acre yard?—Yes, per acre a yard deep.

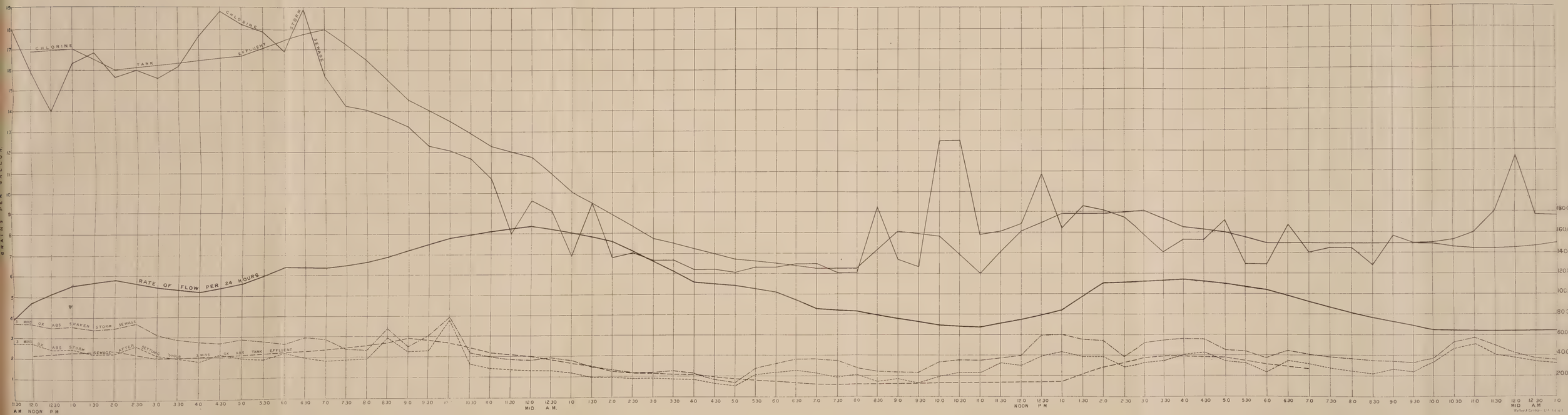
23162. That £50 for Manchester or £41 at Oldham, is the estimated amount of the annual expenditure that may have to be incurred in renewing the filter?—That is the average of the ultimate expenditure, say at the end of five years, averaged out over the year.

23163. Quite so; the estimated expenditure per year spread over five years?—That is it; as a matter of fact we are arranging our finances to lay aside every year so much.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

DIAGRAM HANDED IN BY MR GILBERT J FOWLER D Sc. F.I.C.

Storm. February 15th. 16th. 17th. 1900. February 15th. Thaw of Snow previously fallen: Rain. 9am. to 7pm. February 16th. Showery during morning: Rain at Midnight. February 17th. Showery from Midnight to 3am: Rain at 2pm. Last Day of Rain, February 14th. Total Flow 235,845,000 Gallons. Total Rainfall 24 Inch.



MANCHESTER.

Appendix to Evidence of MR. GILBERT J. FOWLER.

Tables showing average analyses of sewage, tank liquor, and filter effluents at Manchester, April, 1903—December, 1904.

PROCESS OF TREATMENT:

Septic Tanks and Double Contact Beds.

MANCHESTER.

SEWAGE.— Month ending April 22, 1903.

Average daily flow - - - 31,424,000 gallons - Rainfall - - - - - - 0·061 inches.
Maximum daily flow - - 60,000,000 „ - Rainfall - - - - - - 0·330 „
Minimum daily flow - - 15,430,000 „ - Rainfall - - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·09	3·02	2·19
Albuminoid Nitrogen	·29	·85	·51
Oxygen absorbed from $KMnO_4$ in 4 hours	7·36	15·13	10·11
Suspended Solids	—	—	—

Number of samples analysed for the average = 38.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - 4,700,000 gallons.
Amount of Sludge dealt with during the month - - - - - 3,500 tons (No. 2 Tank emptied April 18–28, after 2 years).

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·76	3·88	2·48
Albuminoid Nitrogen	·28	·49	·37
Oxygen absorbed from $KMnO_4$ in 4 hours	6·00	10·97	8·10
Suspended Solids	—	—	—

Number of samples analysed for the average = 20.

FILTERS.—

Total number of times Primary Beds were filled during month - - 790
Number of Primary Beds in use during month - - - - 32
Number of hours Storm Filters were used as Streaming Filters - All beds (except No. 10), 1 hour, March 27; beds 1–6, 1 hour, April 1; bed 13, ⅓ hour, April 4.
Number of times Storm Filters were filled during month - - - 15 beds received 377 fillings; average, $6\frac{17}{20}$ each per week.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours Primary beds, 55 gallons; storm beds, 65 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	·94	·35	3·23	1·53	1·65	·96
Albuminoid Nitrogen	·082	·035	·22	·146	·16	·094
Nitric Nitrogen	·60	1·29	·01	·41	·06	·86
Oxygen absorbed from $KMnO_4$ in 4 hours	·74	·51	4·34	2·00	2·31	1·16
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage loss 9 vols. tap water, 1 vol. sample)	28%	—	98%	—	44%	28%
Suspended Solids	—		—		—	

Number of samples analysed for the average = A. 56, B. 22; A. 8, B. 1 (dissolved oxygen).

REMARKS.—Analytical results in parts per 100,000. 10 acres of Primary Beds not yet mature, receiving from 3 to 5 fillings per week, 12 to 24 hours' contact.

Gilbert J. Fowler
(Superintendent and Chemist).

May 4th, 1903.

MANCHESTER—*continued.*

SEWAGE.— Month ending May 20th, 1903.

Average daily flow	37,261,000 gallons	Rainfall	0·137 inches.
Maximum daily flow	79,460,000 „	Rainfall	0·465 „
Minimum daily flow	18,326,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·06	2·96	2·13
Albuminoid Nitrogen	·20	·74	·48
Oxygen absorbed from $KMnO_4$ in 4 hours	6·87	13·71	10·26
Suspended Solids	—	—	—

Number of samples analysed for the average = 48.

SEPTIC TANKS.—

Average daily flow through the Tanks	5,820,000 gallons.
Amount of Sludge dealt with during the month	2,500 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·00	3·58	2·32
Albuminoid Nitrogen	·165	·506	·35
Oxygen absorbed from $KMnO_4$ in 4 hours	3·54	10·91	7·37
Suspended Solids	5·6	7·6	6·3

Number of samples analysed for the average = 25.

FILTERS.—

Total number of times Primary Beds were filled during month	959.
Number of Primary Beds in use during month	April 29 and May 6, 33; May 13 and 20, 34.
Number of hours Storm Filters were used as Streaming Filters	Beds 1—6, 1 hour, May 4 and Beds 7, 11, 12, 13, 14, 2 hours, May 4.
Number of times Storm Filters were filled during month	15 beds received 357 fillings.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 65 gallons; storm beds, 60 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	·53	·41	2·58	1·47	1·51	·90
Albuminoid Nitrogen	0·7	·047	·27	·104	·17	·10
Nitric Nitrogen	·846	1·45	·235	·33	·194	·74
Oxygen absorbed from $KMnO_4$ in 4 hours	·74	·60	3·91	2·06	2·40	1·20
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage loss 9 vols. tap water, 1 vol. sample.)	22%	15%	69%	33%	38%	22%
Suspended Solids	—		—		—	

Number of samples analysed for the average = A. 85, 10; B. 21, 11 (dissolved oxygen).

June 17th, 1903. *Gilbert J. Fowler.*

MANCHESTER—*continued.*

Month ending June 17th, 1903.

SEWAGE.—

Average daily flow - - - 24,238,000 gallons - Rainfall - - - - - - 0·008 inches.
Maximum daily flow - - 29,700,000 „ - Rainfall - - - - - - 0·055 „
Minimum daily flow - - 17,400,000 „ - Rainfall - - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·90	3·47	2·81
Albuminoid Nitrogen	·96	·50	·66
Oxygen absorbed from $KMnO_4$ in 4 hours	5·61	14·27	11·63
Suspended Solids	—	—	—

Number of samples analysed for the average = 48.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - 6,250,000 gallons.
Amount of Sludge dealt with during the month - - - - - 2,400 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·29	4·70	3·54
Albuminoid Nitrogen	·29	·53	·42
Oxygen absorbed from $KMnO_4$ in 4 hours	4·34	10·69	8·46
Suspended Solids	—	—	—

Number of samples analysed for the average = 25.

FILTERS.—

Total number of times Primary Beds were filled during month - - - 1,032
Number of Primary Beds in use during month - - - - - 34
Number of hours Storm Filters were used as Streaming Filters - - nil
Number of times Storm Filters were filled during month - - - 365
Estimate of amount of Tank Liquor treated per cube yard per 24 hours — Primary beds, 68 gallons; storm beds, 59 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	1·23	·70	3·29	1·76	2·03	1·08
Albuminoid Nitrogen	·14	·07	·28	·16	·20	·11
Nitric Nitrogen	·42	1·47	·01	·54	·09	·95
Oxygen absorbed from $KMnO_4$ in 4 hours	1·20	·66	4·14	2·06	3·11	1·30
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage loss 9 vols. tap water, 1 vol. sample.)	34%	14%	65%	41%	50%	24%
Suspended Solids	—		—		—	

Number of samples analysed for the average = A. 92, B. 24. / 11, 11 (dissolved oxygen).

June 29th, 1903

Gilbert J. Fowler.

MANCHESTER—*continued.*

Month ending July 15th, 1903.

SEWAGE.—

Average daily flow - - 28,809,000 gallons - Rainfall - - - - - 0·088 inches.
Maximum daily flow - 69,765,000 „ - Rainfall - - - - - 0·545 „
Minimum daily flow - - 17,860,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·21	3·55	2·54
Albuminoid Nitrogen	·34	·92	·59
Oxygen absorbed from $KMnO_4$ in 4 hours	7·81	15·14	11·81
Suspended Solids	30·6	38·6	34·4

Number of samples analysed for the average = 48.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - - 5,726,800 gallons.
Amount of Sludge dealt with during the month - - - - - 920 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·88	4·23	3·09
Albuminoid Nitrogen	·26	·59	·38
Oxygen absorbed from $KMnO_4$ in 4 hours	6·11	12·51	8·44
Suspended Solids	7·4	10·6	9·0

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - 943
Number of Primary Beds in use during month - - - - June 24 and July 1, 34; July 8, 38; July 15, 43
Number of hours Storm Filters were used as Streaming Filters - One hour, June 26, 1903; except Beds 3 and 4
Number of times Storm Filters were filled during month - - 442
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - - - - - - - - - - - - Primary beds, 57 gallons; storm beds, 77 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·88	0·29	3·53	1·47	1·80	1·07
Albuminoid Nitrogen	0·07	0·05	0·28	0·15	0·17	·106
Nitric Nitrogen	0·98	1·15	0·01	0·26	·22	·635
Oxygen absorbed from $KMnO_4$ in 4 hours	1·00	0·89	4·83	2·51	2·78	1·44
Dissolved Oxygen taken up in 48 hours, at 80° Fahr. (Percentage loss, 9 vols. tap water 1 vol. sample)	33%	16%	66%	47%	48%	29%
Suspended Solids	—		—		—	

	A.	B.
Number of samples analysed for the average	101	25
„ „ for Dissolved Oxygen	18	14

Gilbert J. Fowler.

July 25th, 1903.

MANCHESTER—*continued.*

SEWAGE.— Month ending August 12th, 1903.

Average daily flow - - - 32,238,000 gallons - Rainfall - - - - - 0·099 inches.
Maximum daily flow - - 62,398,000 „ - Rainfall - - - - - 0·850 „
Minimum daily flow - - 19,389,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·33	2·97	2·34
Albuminoid Nitrogen	0·39	0·69	0·52
Oxygen absorbed from $KMnO_4$ in 4 hours	4·61	13·56	10·35
Suspended Solids	33·4	44·9	37·7

Number of samples analysed for the average = 48.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - 7,690,000 gallons.
Amount of Sludge dealt with during the month - - - - - nil.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·64	3·52	2·61
Albuminoid Nitrogen	0·27	0·43	0·35
Oxygen absorbed from $KMnO_4$ in 4 hours	4·57	8·91	7·40
Suspended Solids	9·4	10·0	9·7

Number of samples analysed for the average = 23.

FILTERS.—

Total number of times Primary Beds were filled during month - - 1,268
Number of Primary Beds in use during month - - - - - July 22 & 29, 43 ; Aug. 5 & 12, 44
Number of hours Storm Filters were used as Streaming Filters - - 1 hour, July 17, 2 hours, July 22.
Number of times Storm Filters were filled during month - - - 465
Estimate of amount of Tank Liquor treated per cube yard per 24 hours Primary beds, 66 gallons ; storm filters, 83 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	1·06	0·35	2·47	1·52	1·65	1·00
Albuminoid Nitrogen	0·09	0·05	0·25	0·15	0·16	0·11
Nitric Nitrogen	0·82	1·12	0·02	0·16	0·27	0·52
Oxygen absorbed from $KMnO_4$ in 4 hours	0·74	0·50	3·34	2·14	2·34	1·34
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage loss, 9 vols. tap water 1 vol. sample.	31%	13%	64%	37%	43%	24%
Suspended Solids	—		—		—	

	A.	B.
Number of samples analysed for the average	117	24
„ „ for Dissolved Oxygen	10	11

Gilbert J. Fowler.

MANCHESTER—*continued.*

SEWAGE.— Month ending September 9th, 1903.

Average daily flow - - - 43,556,000 gallons - Rainfall - - - - - - 0·196 inches.
Maximum daily flow - - 90,765,000 „ Rainfall - - - - - 0·965 „
Minimum daily flow - - - 22,666,000 „ - Rainfall - - - - - —

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·03	3·20	2·03
Albuminoid Nitrogen	0·15	0·72	0·47
Oxygen absorbed from $KMnO_4$ in 4 hours	5·53	14·84	8·39
Suspended Solids	—	—	—

Number of samples analysed for the average = 48.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - 10,300,000 gallons.
Amount of Sludge dealt with during the month - - - - - - 240 tons (September 3rd)

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·12	3·23	2·20
Albuminoid Nitrogen	0·25	0·435	0·34
Oxygen absorbed from $KMnO_4$ in 4 hours	4·40	8·46	6·30
Suspended Solids	—	—	—

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - - - 1,698.
Number of Primary Beds in use during month - - - - - - Aug. 19 and 26, 45 ; Sept. 2, 46 ; Sept. 9, 47.
Number of hours Storm Filters were used as Streaming Filters - - Aug. 14, 2 hours ; Aug. 15, 17, 18, 1 hour daily ; and Aug. 20, 3 hours.
Number of times Storm Filters were filled during month - - - - 225.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - Primary beds, 84 gallons; storm filters, 61 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·53	0·29	2·41	1·29	1·26	0·76
Albuminoid Nitrogen	0·06	0·047	0·235	0·14	0·13	0·09
Nitric Nitrogen	0·77	0·96	0·02	0·16	0·29	0·54
Oxygen absorbed from $KMnO_4$ in 4 hours	0·80	0·60	3·03	2·20	1·84	0·98
Dissolved Oxygen taken up in hours	—		—		—	
Suspended Solids	—		—		—	

Number of samples analysed for the average = A., 143 ; B., 15.

REMARKS.—Storm Beds stopped from August 25th to September 9th inclusive, owing to constructional work

Gilbert J. Fowler.

September 25th, 1903.

MANCHESTER—*continued.*

Month ending October 7th, 1903.

SEWAGE.—

Average daily flow	36,928,000 gallons	Rainfall	0·138 inches.
Maximum daily flow	84,890,000 „	Rainfall	1·160 „
Minimum daily flow	20,945,000 „	Rainfall	—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·20	3·21	2·41
Albuminoid Nitrogen	·34	·90	·59
Oxygen absorbed from $KMnO_4$ in 4 hours	6·73	17·31	10·34
Suspended Solids	18·9	47·1	31·1

Number of samples analysed for the average = 48.

SEPTIC TANKS.—

Average daily flow through the Tanks	11,000,000 gallons.
Amount of Sludge dealt with during the month	None.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·70	4·23	3·05
Albuminoid Nitrogen	·26	·53	·40
Oxygen absorbed from $KMnO_4$ in 4 hours	5·77	10·11	8·00
Suspended Solids	11·4	15·1	13·4

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month	1,831.
Number of Primary Beds in use during month	Sept. 16 and 23 = 47. Sept. 30 and Oct. 7 = 51.
Number of hours Storm Filters were used as Streaming Filters	1 hour, Sept. 10; 2 hours, Sept. 11; 1 hour, Sept. 24.
Number of times Storm Filters were filled during month	491.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 83 gallons; storm filters, 96 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B
Ammoniacal Nitrogen	·41	·35	3·29	1·43	1·76	1·01
Albuminoid Nitrogen	·07	·047	·26	17	·16	·12
Nitric Nitrogen	·87	3·52	nil	·01	·30	·73
Oxygen absorbed from $KMnO_4$ in 4 hours	·89	·74	5 23	2·37	2·54	1·57
Dissolved Oxygen taken up in hours	—	—	—	—	—	—
Suspended Solids	—		—		—	

Number of samples analysed for the average = A., 148; B., 28.

Gilbert J. Fowler.

October 26th, 1903.

MANCHESTER—*continued.*

Month ending November 4th, 1903.

SEWAGE.—

Average daily flow	53,618,000 gallons	Rainfall	0·233 inches
Maximum daily flow	113,815,000 „	Rainfall	1·180 „
Minimum daily flow	22,400,000 „	Rainfall	nil

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·70	3·41	1·67
Albuminoid Nitrogen	0·20	0·82	0·39
Oxygen absorbed from $KMnO_4$ in 4 hours	5·20	12·40	7·66
Suspended Solids	19·7	47·7	29·3

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - 14,250,000 gallons.

Amount of Sludge dealt with during the month - - - - - 915 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·82	3·65	1·74
Albuminoid Nitrogen	0·19	0·53	0·27
Oxygen absorbed from $KMnO_4$ in 4 hours	4·34	9·60	6·10
Suspended Solids	8·3	9·4	9·0

Number of samples analysed for the average = 22.

FILTERS.—

Total number of times Primary Beds were filled during month - - 2,432

Number of Primary Beds in use during month - - - - - 51

Number of hours Storm Filters were used as Streaming Filters - - Oct. 8, 2 hours; 14, 3 hours; 20, 1 hour; 23, 1 hour; 27, 2 hours; 28, 3 hours; 30, 1 hour; Nov. 2, 3 hours. Total 16 hours.

Number of times Storm Filters were filled during month - - - 765

Estimate of amount of Tank Liquor treated per cube yard per 24 hours — Primary beds, 104 gallons; storm filters, 109 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·69	0·18	1·42	2·06	1·12	0·63
Albuminoid Nitrogen	0·07	0·01	0·12	0·18	0·10	0·06
Nitric Nitrogen	0·60	0·92	0·17	nil	0·34	0·47
Oxygen absorbed from $KMnO_4$ in 4 hours	1·44	0·51	2·54	2·69	1·87	1·1
Dissolved Oxygen taken up in 48 hours at 80° F. (9 vols. tap water, 1 vol. sample)	16%	6%	26%	28%	22%	18%
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average	141	62
„ „ „ dissolved oxygen	3	3

Gilbert J. Fowler.

MANCHESTER—*continued.*

SEWAGE. Month ending December 2nd, 1903.

Average daily flow	46,359,000 gallons	Rainfall	0·106 inches.
Maximum daily flow	98,698,000 „	Rainfall	0·450 „
Minimum daily flow	30,687,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·17	2·65	2·03
Albuminoid Nitrogen	0·18	0·78	0·48
Oxygen absorbed from $KMnO_4$ in 4 hours	6·11	14·51	10·20
Suspended Solids	25·1	39·4	33·7

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks	11,325,000 gallons.
Amount of Sludge dealt with during the month	2,500 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·53	3·35	2·45
Albuminoid Nitrogen	0·20	0·45	0·35
Oxygen absorbed from $KMnO_4$ in 4 hours	6·00	12·63	8·32
Suspended Solids	10·3	10·9	10·6

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month	1,971
Number of Primary Beds in use during month	51
Number of hours Storm Filters were used as Streaming Filters	Nov. 25, 1 hour; Nov. 26 and 27, 1 hour; and Nov. 28, 3 hours. Total, 6 hours.
Number of times Storm Filters were filled during month	679
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 82 gallons; storm filters, 85 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·88	0·29	2·41	2·17	1·54	1·08
Albuminoid Nitrogen	0·05	0·023	0·20	0·25	0·13	0·10
Nitric Nitrogen	0·81	0·92	0·01	0·07	0·30	0·48
Oxygen absorbed from $KMnO_4$ in 4 hours	1·14	0·76	5·20	4·06	2·59	1·73
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage loss : 9 vols. tap water, 1 vol. sample)	15%	14%	52%	43%	37 %	28%
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average	144	46
„ „ „ dissolved oxygen test	8	8

Gilbert J. Fowler.

December 15th, 1903.

6225—Ap. I.

MANCHESTER—*continued.*

SEWAGE.— Month ending December 30th, 1903.

Average daily flow	29,238,000 gallons	Rainfall	0·034 inches.
Maximum daily flow	53,014,000 „	Rainfall	0·270 „
Minimum daily flow	17,453,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·78	4·47	2·66
Albuminoid Nitrogen	·30	·98	·55
Oxygen absorbed from $KMnO_4$ in 4 hours	7·89	16·40	12·11
Suspended Solids	23·4	40·3	31·6

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks	275,770,000 gallons.
Amount of Sludge dealt with during the month	5,200 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·47	4·82	3·32
Albuminoid Nitrogen	·19	·69	45
Oxygen absorbed from $KMnO_4$ in 4 hours	6·86	14·40	9·83
Suspended Solids	7·9	9·4	8·6

Number of samples analysed for the average = 21.

FILTERS.—

Total number of times Primary Beds were filled during month	1,719
Number of Primary Beds in use during month	51
Number of hours Storm Filters were used as Streaming Filters	3 hours, December 9th.
Number of times Storm Filters were filled during month	671
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 72 gallons; storm filters, 74 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	·82	·70	3·00	2·18	1·90	1·46
Albuminoid Nitrogen	·06	·047	·30	·247	·176	·135
Nitric Nitrogen	1·08	1·29	·02	·19	·41	·62
Oxygen absorbed from $KMnO_4$ in 4 hours	1·54	·74	5·57	4·11	3·19	2·47
Dissolved Oxygen taken up in 48 hours at 80° F. (Percentage loss: 9 vols. tap water, 1 vol. sample)	24%	—	61%	—	46%	—
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average	123	44
„ „ „ „ dissolved oxygen	4	

Gilbert J. Fowler.

January 22nd, 1904.

MANCHESTER—*continued.*

SEWAGE.— Month ending January 27th, 1904.

Average daily flow - - - 31,994,000 gallons - Rainfall - - - - - 0·071 inches.
Maximum daily flow - - 75,981,000 „ - Rainfall - - - - - 0·515 „
Minimum daily flow - - 18,920,000 „ - Rainfall - - - - - —

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·76	4·53	2·50
Albuminoid Nitrogen	0·26	0·87	0·55
Oxygen absorbed from $KMnO_4$ in 4 hours	8·11	15·37	11·43
Suspended Solids	32·3	37·7	35·4

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - 11,850,000 gallons.
Amount of Sludge dealt with during the month - - - - - 2,860 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·93	4·53	2·75
Albuminoid Nitrogen	0·19	0·63	0·45
Oxygen absorbed from $KMnO_4$ in 4 hours	6·97	12·51	9·91
Suspended Solids	11·4	11·7	11·6

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - - - 2,090.
Number of Primary Beds in use during month - - - - - - 51.
Number of hours Storm Filters were used as Streaming Filters - - - Jan. 13, 1 hour; Jan. 15, 15 minutes; 7 beds only
Number of times Storm Filters were filled during month - - - - 768.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - Primary beds, 86 gallons; storm filters, 78 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A	B	A.	B.	A.	B.
Ammoniacal Nitrogen	0·65	0·41	3·18	2·47	1·72	1·39
Albuminoid Nitrogen	0·06	0·03	0·29	0·29	0·16	0·13
Nitric Nitrogen	0·92	1·01	0·03	0·07	0·49	0·60
Oxygen absorbed from $KMnO_4$ in 4 hours	1·63	1·09	6·29	4·31	3·29	2·53
Dissolved Oxygen taken up in 48 hours at 80° F. (9 vols. tap water, 1 vol. sample)	29%	—	56%	—	43%	—
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average - - =	141	48
„ „ „ dissolved oxygen - - =	4	

Gilbert J. Fowler.

MANCHESTER—*continued.*

SEWAGE.— Month ending February 24th, 1904.

Average daily flow	37,662,000 gallons	Rainfall	0·117 inches.
Maximum daily flow	83,471,000 „	Rainfall	0·55 „
Minimum daily flow	24,862,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·18	2·94	1·89
Albuminoid Nitrogen	0·13	0·69	0·435
Oxygen absorbed from $KMnO_4$ in 4 hours	6·91	14·74	10·80
Suspended Solids	25·2	35·7	29·3

Number of samples analysed for the average=24.

SEPTIC TANKS.—

Average daily flow through the Tanks	13,231,000 gallons.
Amount of Sludge dealt with during the month	nil.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·05	3·17	1·96
Albuminoid Nitrogen	0·13	0·52	0·31
Oxygen absorbed from $KMnO_4$ in 4 hours	5·71	10·46	8·29
Suspended Solids	7·7	15·4	11·6

Number of samples analysed for the average=23.

FILTERS.—

Total number of times Primary Beds were filled during month	2,360
Number of Primary Beds in use during month	51
Number of hours Storm Filters were used as Streaming Filters	Feb. 4, 2 hours; Feb. 8, 2 hours.
Number of times Storm Filters were filled during month	911
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 96 gallons; storm filters, 90 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·70	0·47	2·23	1·76	1·43	1·07
Albuminoid Nitrogen	0·035	0·02	0·26	0·19	0·13	0·09
Nitric Nitrogen	1·01	1·17	0·06	0·44	0·46	0·635
Oxygen absorbed from $KMnO_4$ in 4 hours	1·37	0·86	4·94	3·23	2·84	2·04
Dissolved Oxygen taken up in hours	—	—	—	—	—	—
Suspended Solids	—	—	—	—	—	—

Number of samples analysed for the average— A. 132, B. 52

Gilbert J. Fowler.

MANCHESTER—*continued.*

SEWAGE.— Five weeks ending March 30th, 1904.

Average daily flow - - - 29,002,000 gallons - Rainfall - - - - - 0·052 inches.
Maximum daily flow- - - 67,671,000 „ - Rainfall - - - - - 0·325 „
Minimum daily flow- - - 19,351,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

	Best.	Worst.	Average
Ammoniacal Nitrogen	0·94	3·12	2·35
Albuminoid Nitrogen	0·26	0·70	0·49
Oxygen absorbed from $KMnO_4$ in 4 hours	8·57	14·91	11·94
Suspended Solids	23·4	32·0	28·6

Number of samples analysed for the average=30.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - - 11,149,430 gallons.
Amount of sludge dealt with during the period - - - - - none.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·29	3·94	2·72
Albuminoid Nitrogen	0·19	0·60	0·40
Oxygen absorbed from $KMnO_4$ in 4 hours	7·89	12·51	10·09
Suspended Solids	7·7	12·6	9·7

Number of samples analysed for the average=29.

FILTERS.—

Total number of times Primary Beds were filled during period - - 2,510.
Number of Primary Beds in use during period - - - - - 51.
Number of hours Storm Filters were used as Streaming Filters - - March 14, 3½ hours.
Number of times Storm Filters were filled during period - - - 965.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours Primary beds, 81 gallons; storm filters, 75 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·82	0·59	2·41	2·29	1·68	1·37
Albuminoid Nitrogen	0·05	0·035	0·23	0·235	0·15	0·12
Nitric Nitrogen	0·80	1·01	0·02	0·235	0·38	0·52
Oxygen absorbed from $KMnO_4$ in 4 hours	1·54	0·86	5·14	4·14	3·31	2·59
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage reduction, 9 vols. tap water, 1 vol. sample)	31	30	64	57	48	42
Suspended Solids	—		—		—	

	A.	B.
Number of samples analysed for the average	176	58
„ „ for Dissolved Oxygen	22	11

Gilbert J. Fowler.

MANCHESTER—*continued*

Month ending April 27th, 1904.

SEWAGE.—

Average daily flow - - - 29,484,000 gallons - Rainfall - - - - - 0·071 inches.
Maximum daily flow - - - 44,957,000 „ - Rainfall - - - - - 0·340 „
Minimum daily flow - - 18,944,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·29	2·88	2·19
Albuminoid Nitrogen	·25	·70	·47
Oxygen absorbed from $KMnO_4$ in 4 hours	5·10	15·40	10·84
Suspended Solids	26·9	45·1	33·1

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - - 11,888,150 gallons.
Amount of Sludge dealt with during the month - - - - - - 1,420 tons.

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·23	3·29	2·40
Albuminoid Nitrogen	·20	·52	·34
Oxygen absorbed from $KMnO_4$ in 4 hours	5·37	12·30	9·44
Suspended Solids	11·4	15·0	12·9

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - - - - 2,109
Number of Primary Beds in use during month - - - - - - - 51
Number of hours Storm Filters were used as Streaming Filters - - - —
Number of times Storm Filters were filled during month - - - - - 804
Estimate of amount of Tank Liquor treated per cube yard per 24 hours —
Primary Beds, 84. Storm Filters, 75.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm-filters.

———	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	·59	·47	2·53	2·11	1·57	1·12
Albuminoid Nitrogen	·06	·035	·21	·16	·12	·09
Nitric Nitrogen	1·08	1·01	·09	·28	·49	·56
Oxygen absorbed from $KMnO_4$ in 4 hours	1·31	·86	6·37	4·20	2·96	2·10
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (Percentage reductions, 9 vols. tap water, 1 vol. sampel)	19°/₀	13°/₀	65°/₀	42°/₀	36°/₀	25°/₀
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average	67	48
„ „ „ for dissolved oxygen test	14	8

Gilbert J. Fowler.

June 13th, 1904.

MANCHESTER—*continued.*

Month ending May 25, 1904.

SEWAGE—

Average daily flow	26,373,000 gallons	Rainfall	0·057 inches.
Maximum daily flow	36,753,000 „	Rainfall	0·240 „
Minimum daily flow	18,758,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·70	3·88	2·66
Albuminoid Nitrogen	0·28	0·83	0·51
Oxygen absorbed from $KMnO_4$ in 4 hours	9·54	17·43	13·04
Suspended Solids	27·0	40·0	33·1

Number of samples analysed for the average = 24.

SEPTIC TANKS—

Average daily flow through the Tanks	9,552,860 gallons.
Amount of Sludge dealt with during the month	9,540 tons

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·82	3·94	2·91
Albuminoid Nitrogen	0·27	0·54	0·40
Oxygen absorbed from $KMnO_4$ in 4 hours	7·90	13·50	11·13
Suspended Solids	12·6	15·7	14·6

Number of samples analysed for the average = 24.

FILTERS—

Total number of times Primary Beds were filled during month	1,800
Number of Primary Beds in use during month	May 4, 11, 18, = 51 ; May 25 = 52
Number of hours Storm Filters were used as Streaming Filters	—
Number of times Storm Filters were filled during month	812
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	—

Primary Beds, 69. Storm Filters, 74.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	1·18	0·70	2·29	2·17	1·78	1·28
Albuminoid Nitrogen	0·08	0·06	0·23	0·21	0·15	0·11
Nitric Nitrogen	1·41	1·18	0·06	0·01	0·41	0·53
Oxygen absorbed from $KMnO_4$ in 4 hours	1·97	1·20	4·26	4·23	3·30	2·59
Dissolved Oxygen taken up in 48 hours (percentage reduction) at 80° Fahr. (9 vols. tap water, 1 vol. sample)	20%	11%	62%	43%	36%	29%
Suspended Solids	4·0	—	6·0	—	4·7	—

	A.	B.
Number of samples analysed for the average	71	48
„ „ for Dissolved Oxygen Test	23	12

Gilbert J. Fowler.

June 13th, 1904.

MANCHESTER—*continued.*

SEWAGE.— Month ending June 22nd, 1904.

Average daily flow - - - 27,923,000 gallons - Rainfall - - - - - - 0·062 inches.
Maximum daily flow - - 52,414,000 „ - Rainfall - - - - - - 0·625 „
Minimum daily flow - - 17,966,000 „ - Rainfall - - - - - - —

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·59	4·40	2·86
Albuminoid Nitrogen	·21	1·03	·57
Oxygen absorbed from $KMnO_4$ in 4 hours	5·77	18·69	11·63
Suspended Solids	23·7	37·7	30·4

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - - - 10,665,350 gallons.
Amount of Sludge dealt with during the month - - - - - - 6,230 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·35	4·70	3·22
Albuminoid Nitrogen	·14	·54	·39
Oxygen absorbed from $KMnO_4$ in 4 hours	4·92	14·10	9·30
Suspended Solids	5·7	14·3	10·9

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - - 2,037
Number of Primary Beds in use during month - - - - - 52
Number of hours Storm Filters were used as Streaming Filters - —
Number of times Storm Filters were filled during month - - - 771
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - Primary beds, 76 gallons; storm filters, 71 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	1·41	·41	2·47	1·96	1·74	1·19
Albuminoid Nitrogen	·05	·02	·25	·22	·17	·13
Nitric Nitrogen	·88	1·12	·09	·02	·40	·55
Oxygen absorbed from $KMnO_4$ in 4 hours	1·17	·74	5·83	3·52	2·85	2·04
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (percentage loss, 9 vols. tap water, 1 vol. sample)	10%	6%	52%	41%	32%	24%
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average	70	48
„ „ for Dissolved Oxygen	18	10

July 7th, 1904. *Gilbert J. Fowler.*

MANCHESTER—*continued.*

Month ending July 20, 1904.

SEWAGE.—

Average daily flow	27,567,000 gallons.	Rainfall	·033 inches.
Maximum daily flow	36,295,000 „	Rainfall	·165 „
Minimum daily flow	20,241,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·94	3·35	2·42
Albuminoid Nitrogen	0·32	1·41	0·64
Oxygen absorbed from $KMnO_4$ in 4 hours	8·23	17·66	10·84
Suspended Solids	26·3	33·2	30·3

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks	10,987,140 gallons.
Amount of Sludge dealt with during the Month	10,220 tons

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·06	3·59	2·57
Albuminoid Nitrogen	0·20	0·49	0·33
Oxygen absorbed from $KMnO_4$ in 4 hours	7·14	10·06	8·37
Suspended Solids	11·4	12·6	12·1

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month	2,093
Number of Primary Beds in use during month	52
Number of hours Storm Filters were used as Streaming Filters	—
Number of times Storm Filters were filled during month	709
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 79 gallons; storm filters, 62 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·88	0·65	2·17	1·65	1·40	1·03
Albuminoid Nitrogen	0·07	0·06	0·28	0·21	0·15	0·12
Nitric Nitrogen	0·82	0·86	nil.	0·02	0·26	0·32
Oxygen absorbed from $KMnO_4$ in 4 hours	1·86	0·89	3·37	3·20	2·51	2·03
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (per cent. loss, 9 vols. tap water, 1 vol. sample)	16%	8%	32%	43%	25%	24%
Suspended Solids	5·4	—	6·0	—	5·7	—

Number of samples analysed for the average = A. 69, B. 48
„ „ „ „ for Dissolved Oxygen Test = A. 11, B. 6

Gilbert J. Fowler.

July 29th, 1904.

MANCHESTER—*Continued.*

Month ending August 17, 1904.

SEWAGE.—

Average daily flow - - 32,870,000 gallons - Rainfall - - - - - 0·113 inches.
Maximum daily flow - - 66,724,000 „ - Rainfall - - - - - 0·560 „
Minimum daily flow - - 20,226,000 „ - Rainfall - - - - - nil.

Average analysis of sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·00	3·29	2·07
Albuminoid Nitrogen	0·31	0·87	0·51
Oxygen absorbed from $KMnO_4$ in 4 hours	4·34	11·94	8·23
Suspended Solids	27·2	31·4	26·4

Number of samples analysed for the average = 24.

SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - - 12,038,000 gallons.
Amount of Sludge dealt with during the month - - - - - - nil.

Average analysis of tank liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·53	3·59	2·48
Albuminoid Nitrogen	0·21	0·41	0·26
Oxygen absorbed from $KMnO_4$ in 4 hours	4·40	8·17	6·30
Suspended Solids	7·4	11·4	9·1

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - 2,267
Number of Primary Beds in use during month - - - - - July 27 and August 3 = 68 August 10 and 17 = 69.
Number of hours Storm Filters were used as Streaming Filters - August 4, 2 hours (1-15 plot); August 17, 3 hours.
Number of times Storm Filters were filled during the month - 898.
Estimate of amount of Tank Liquor treated per cube yard per 24 hours *Primary beds, 65 gallons; storm filters, 88 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·82	0.41	1·87	1·35	1·29	0·91
Albuminoid Nitrogen	0·08	0·06	0·18	0·16	0·12	0·10
Nitric Nitrogen	0·84	0·89	0·01	nil.	0·33	0·36
Oxygen absorbed from $KMnO_4$ in 4 hours	1·20	0·86	2·80	3·43	1·81	1·63
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (percentage loss, 9 vols. tap water, 1 vol. sample	8%	11%	30%	28%	20%	18%
Suspended Solids	—		—		—	

	A.	B.
Number of samples analysed for the average.	90	49
„ „ „ for Dissolved Oxygen Test	12	6

REMARKS.—*New half-acre beds not yet matured.

Gilbert J. Fowler.

September 9th, 1904.

MANCHESTER—*continued.*

Month ending September 14, 1904.

SEWAGE.—

Average daily flow	33,520,000 gallons	Rainfall	0·096 inches
Maximum daily flow	108,230,000 „	Rainfall	0·835 „
Minimum daily flow	18,944,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·82	4·03	2·20
Albuminoid Nitrogen	0·21	0·95	0·56
Oxygen absorbed from $KMnO_4$ in 4 hours	5·37	14·74	10·04
Suspended Solids	29·4	40·6	35·3

Number of samples analysed for the average = 28.

SEPTIC TANKS.—

Average daily flow through the Tanks - 13,505,000 gallons.

Amount of Sludge dealt with during the month - —

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·94	4·56	2·78
Albuminoid Nitrogen	0·21	0·44	0·34
Oxygen absorbed from $KMnO_4$ in 4 hours	4·12	11·49	7·90
Suspended olids	7·1	15·7	10·1

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - 2,534

Number of Primary Beds in use during month - Aug. 24, 70; Aug. 31, 71; Sept. 7, 73; Sept. 14, 75.

Number of hours Storm Filters were used as Streaming Filters - Aug. 22, 3 hours (16–29, 6 hours), Aug. 23, 1–15 plot, 3 hours (6 beds, 5 hours); Sept. 3, 16–29 plot, 3 hours; 1–15 plot, 2 hours.

Number of times Storm Filters were filled during month - 803

Estimate of amount of Tank Liquor treated per cube yard per 24 hours - *Primary beds, 70 gallons; storm filters, 83 gallons.

A.—Primary Beds. B.—Storm Filters.

Average Analysis of Filter Effluent.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·64	0·24	1·88	1·64	1·40	1·01
Albuminoid Nitrogen	0·09	0·03	0·24	0·21	0·15	0·11
Nitric Nitrogen	0·89	1·10	0·02	0·12	0·36	0·53
Oxygen absorbed from $KMnO_4$ in 4 hours	1·23	0·60	2·54	3·29	2·27	1·93
Dissolved Oxygen taken up in 48 hours at 80° Fahr. (percentage loss, 9 vols. tap water, 1 vol. sample)	20%	20%	50%	39%	33%	29%
Suspended Solids	—	—	—	—	—	—

	A.	B.
Number of samples analysed for the average	60	54
„ „ for Dissolved Oxygen Test	13	6

* New half-acre beds not yet matured, included.

Gilbert J. Fowler.

September 20, 1904.

MANCHESTER—*continued.*

Month ending October 12th, 1904.

SEWAGE.—

Average daily flow	24,483,000 gallons	Rainfall	0·042 inches
Maximum daily flow	43,096,000 „	Rainfall	0·500 „
Minimum daily flow	14,579,000 „	Rainfall	Nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·23	3·70	2·90
Albuminoid Nitrogen	0·49	1·07	0·73
Oxygen absorbed from $KMnO_4$, in 4 hours	8·92	16·30	12·40
Suspended Solids	28·6	38·6	33·3

Number of samples analysed for the average = 28.

SEPTIC TANKS.—

Average daily flow through the Tanks	14,453,570 gallons
Amount of Sludge dealt with during the month	—

Average Analysis of Tank Liquor.

——	Best.	Worst.	Average.
Ammoniacal Nitrogen	2·76	5·11	3·73
Albuminoid Nitrogen	0·27	0·61	0·45
Oxygen absorbed from $KMnO_4$ in 4 hours	7·37	12·97	10·50
Suspended Solids	8·6	11·4	9·4

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month	2,751.
Number of Primary Beds in use during month	Sept. 21, 76 ; Sept. 28, 78 ; Oct. 5 77 ; Oct. 12, 79.
Number of hours Storm Filters were used as Streaming Filters	Sept. 30, 3 hours 1–15 : Oct. 1, 3 hours 16–29 ; Oct. 6, 1 hour 16–23.
Number of times Storm Filters were filled during month	765
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 70 gallons ; storm filters, 71 gallons.

A.—Primary Beds. B.—Storm Filters.

Average Analysis of Filter Effluent.

——	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	1·35	1·08	3·17	2 18	1·96	1·53
Albuminoid Nitrogen	0·09	0·08	0·28	0·26	0·18	0·16
Nitric Nitrogen	0·50	1·13	Nil	0·07	0·26	0·48
Oxygen absorbed from $KMnO_4$ in 4 hours	2·00	1·17	5·66	4·72	3·19	2·84
Dissolved Oxygen taken up in 48 hours (percentage loss at 80° F., 9 vols. tap water, 1 vol. sample)	28%	22%	53%	80%	41%	47%
Suspended Solids	4·3	—	6·6	—	5.4	—

	A.	B.
Number of samples analysed for the average	87	47
„ „ „ for Dissolved Oxygen Test	18	15

Gilbert J. Fowler,

October 29, 1904. Consulting Chemist.

MANCHESTER—*continued.*

Month ending November 9th, 1904.

SEWAGE.—

Average daily flow	26,383,000 gallons	Rainfall	0·091 inches.
Maximum daily flow	74,013,000 „	Rainfall	0·890 „
Minimum daily flow	13,332,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen	0·94	4·35	2·87
Albuminoid Nitrogen	0·31	1·03	0·69
Oxygen absorbed from $KMnO_4$ in 4 hours	7·54	18·57	12·67
Suspended Solids	25·7	40·1	32·7

Number of samples analysed for the average = 28.

SEPTIC TANKS.—

Average daily flow through the Tanks	17,510,000 gallons.
Amount of sludge dealt with during the month	4,700 tons.

Average Analysis of Tank Liquor

	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·23	4·82	3·44
Albuminoid Nitrogen	0·21	0·67	0·47
Oxygen absorbed from $KMnO_4$ in 4 hours	6·34	15·94	10·89
Suspended Solids	9·1	15·1	11·0

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month	3,396
Number of Primary Beds in use during month	Oct. 19, 26, & Nov. 2, 79; Nov. 9, 80
Number of hours Storm Filters were used as Streaming Filters	Oct. 17, beds 1, 3, 7, 8, and 11, 2 hours; beds 16–29, 3 hours; Oct. 18, beds 18–23, 2 hours; Nov. 7, beds 1–6, 8, 9, 12 and 13, 1 hour; Nov. 8, beds 1–15 (except 7 and 11) 1 hour, and all beds 1–15, 1 hour 2nd filling, also 16–29, 1 hour; Nov. 9, beds 1–15 (except 7 and 11) 3 hours: beds 17, 18, 19, 20, 21, 22, 23, 25 and 26, 2 hours.
Number of times Storm Filters were filled during month	776
Estimate of amount of Tank Liquor treated per cube yard per 24 hours	Primary beds, 82 gallons; storm filters, 76 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

	Best.		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·65	0·47	3·29	3·29	1·96	1·80
Albuminoid Nitrogen	0·09	0·07	0·31	0·29	0·19	0·18
Nitric Nitrogen	0·66	0·77	nil.	nil.	0·25	0·235
Oxygen absorbed from $KMnO_4$ in 4 hours	1·23	1·03	6·94	6·17	3·40	3·53
Dissolved Oxygen taken up in 48 hours at 80° Fahr. Percentage loss (9 vols. tapwater, 1 vol. sample)	6°/₀	12°/₀	48°/₀	100°/₀	29°/₀	43°/₀
Suspended Solids	4·6	—	7·4	—	6·1	—

	A.	B.
Number of samples analysed for the average	110	53
„ „ for Dissolved Oxygen Test	11	11

Gilbert J. Fowler.

November 30, 1904.

MANCHESTER—*continued.*

SEWAGE.— Month ending December 7th, 1904.

Average daily flow - - 28,937,000 gallons - Rainfall - - - - - 0·062 inches.
Maximum daily flow - 51,155,000 „ - Rainfall - - - - - 0·390 „
Minimum daily flow - 14,882,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·35	3·76	2·36
Albuminoid Nitrogen	0·36	0·92	0·59
Oxygen absorbed from $KMnO_4$ in 4 hours	8·46	15·37	12·67
Suspended Solids	30·3	44·6	36·6

Number of samples analysed for the average = 28.

*SEPTIC TANKS.—

Average daily flow through the Tanks - - - - - - - - - - 20,523,000 gallons.
Amount of Sludge dealt with during the month - - - - - - - - -

Average Analysis of Tank Liquor.

———	Best.	Worst.	Average.
Ammoniacal Nitrogen	1·53	4·70	2·52
Albuminoid Nitrogen	0·27	0·64	0·45
Oxygen absorbed from $KMnO_4$ in 4 hours	7·54	15·94	10·79
Suspended Solids	13·4	23·1	17·0

Number of samples analysed for the average = 24.

FILTERS.—

Total number of times Primary Beds were filled during month - - - 3,886
Number of Primary Beds in use during month - - - - - - 81
Number of hours Storm Filters were used as Streaming Filters - - November 21, 16—29 beds, 2 hours; December 7, 16—29 beds, 2 hours.
Number of times Storm Filters were used during month - - - - 1,060
Estimate of amount of Tank Liquor treated per cube yard per 24 hours - Primary Beds, 94 gallons; Storm Filters, 77 gallons.

Average Analysis of Filter Effluent.

A.—Primary Beds. B.—Storm Filters.

———	Best		Worst.		Average.	
	A.	B.	A.	B.	A.	B.
Ammoniacal Nitrogen	0·88	0·82	3·12	3 12	1·63	1·59
Albuminoid Nitrogen	0·07	0·07	0·34	0·25	0·16	0·15
Nitric Nitrogen	0·68	0·80	nil.	0·07	0·32	0 35
Oxygen absorbed from $KMnO_4$ in 4 hours	1·37	1·31	6·31	5·63	3·46	3·50
Dissolved Oxygen taken up in 48 hours at 80° Fahr. Percentage Loss (9 vols. tap water, 1 vol. sample)	20%	8%	48%	79%	30%	36%
Suspended Solids	4·9	—	5·7	—	5·4	—

	A.	B.
Number of samples analysed for the average =	116	48
„ „ „ dissolved O. test =	10	10

REMARKS.—Full supply of town's water resumed November 13th, 1904.

* The great variation in the analytical figures for the best and worst samples is due to excessive quantities of suspended matter passing away in the tank effluent.

December 21st, 1904.

Gilbert J. Fowler.

SEVENTY-SIXTH DAY.

Monday, 15th May, 1905.

PRESENT.

The Right: Hon. the Earl of Iddesleigh (*Chairman*) presiding.
Major-General Constantine Phipps Carey, C.B., R.E.
Sir William Ramsay, K.C.B., F.R.S
Colonel T. W. Harding, J.P.

Mr. F. J. Willis (*Secretary*).

ALSO PRESENT.

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. J. Carter Bell, A.R.S.M., etc., Borough Analyst of Salford, called in; and Examined.

Mr. J. Carter Bell, A.R.S.M.

15 May 1905.

23164. (*Chairman.*) You are Mr. J. Carter Bell, Analyst to the County of Chester and for the County Boroughs of Salford, Birkenhead, Congleton, Stalybridge, and Glossop?—Yes.

23165. You have attended here to-day to give evidence with regard to the sewage works of the County Borough of Salford?—Yes.

23166. Now, just let me ask you what is the general treatment at Salford?—The general treatment is precipitation with chemicals and passing through roughing filters, and then through a final continuous filter.

23167. What is the population draining to the Salford works?—231,514.

23168. What is the system of drainage—that is to say, is the storm water either wholly or partially drained into a separate system, and, if only partially, to what extent?—The drainage is entirely on the combined system.

23169. Is there any infiltration of subsoil water into the sewers?—Yes, there is considerable infiltration of subsoil water, probably from 1,000,000 to 3,000,000 gallons per day, according to weather.

23170. What is the water supply per head, and from what source does it come?—Water supply from Manchester Corporation, estimated about 15 gallons per per head for domestic purposes, and equal to about 5 gallons per head for trade purposes.

23171. Is it hard or soft water?—It is very soft.

23172. What is the drainage area of the part of the town which is sewered?—Probably 50 per cent.

23173. What proportion of the population use pail closets or middens, and what proportion use water-closets?—The number of pail closets or middens is 15,691, and the number of water-closets 22,872.

23174. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather (1) in winter and (2) in summer?—The quantity pumped, as automatically recorded—dry weather flow 8,000,000 gallons per day; other flows only estimated, being not yet fully treated owing to insufficient pumping force.

23175. What is the maximum dry weather rate of flow, and at what hour does this occur?—The maximum dry weather rate of flow equals 14,000,000 gallons per day, and this occurs about 3 p.m.

23176. What is the minimum dry weather rate of flow, and at what hour does this occur?—The minimum dry weather rate is about 3,000,000 gallons per day, and this occurs about 6 a.m.

23177. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—We have no record of this.

23178. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation? For comparative purposes kindly give the maximum and minimum rates of flow in dry weather in the sewers on which the various overflows are situated?—There are many storm overflows to the seven miles' length of river flowing through the borough. We have no records of the flow.

23179. What is the largest number of gallons of sewage which have passed the last storm overflow and come to your works in 24 hours?—I cannot say.

23180. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—No.

23181. Can you give the Commission an approximate statement as to (a) the volume of sewage which comes to your works during the year; and (b) the volume which passes over your overflows?—The volume of sewage which comes to the works during the year is approximately 3,355,081,000 gallons. I cannot say what volume passes over the overflows.

23182. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one time and another time entering the sewers from this source?—The infiltration of subsoil water varies. I cannot say what extra amount of liquid enters the sewers from this source.

23183. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of those effluents?—I am unable to say.

23184. Has your authority framed any rules as to the reception of trade effluents into sewers? If so, what are they?—No rules are enforced.

23185. Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise? If so, would you kindly tell us what your difficulties are?—We have not found any difficulty. Sometimes tarry matter affects the oxygen test.

23186. In dry weather what is the average amount of suspended matter in your sewage, and what are the highest and lowest figures in parts per 100,000?—The average amount in summer is 41·4 parts per 100,000; the highest was 564·3 parts per 100,000 (April 18th, 1904); and the lowest (April 15th, 1904) was 5·7 parts per 100,000.

23187. What is the physical character of these solids?—Physically it is black slime. Chemically it consists of organic matter, 54·08 parts per 100,000; silica, 21·77; oxide of iron, 12·1; alumina, 4·8; lime, 6·2; copper, 1·0. I do not mean to say that the sludge always contains copper: it has only been analysed two or three times, and each time it contained copper.

23188. Can you give us average analyses of your sewage for the years 1903 and 1904 in summer and in winter?—The average analyses were as follow:—

	Parts per 100,000. Summer.	Winter.
Four hours' oxygen absorbed	6·8	6·9
Suspended matter	41·4	38·7
Alkalinity as lime	·8	·6

23189. Is it a "strong" sewage?—Yes.

Mr. J. Carter Bell, A.R.S.M.

15 May 1905.

23190. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—Yes, it does vary; but it does not affect the final effluent.

23191. How do you think "strength" of sewage as affecting purification is best expressed or measured?—By stating the percentage of purification derived from the oxygen test.

23192. Have you any information as to the bacteriological condition of your sewage in dry weather and in storm times?—No.

23193. Are there any chemical poisons in your sewage? If so, what are they, and to what extent do they occur?—There are trade effluents, but I should not call them poisonous.

23194. Is your sewage always alkaline?—Practically speaking, it is alkaline.

23195. Do you find that the amounts of suspended solids are increased or diminished in times of storm, and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—The suspended solids are increased at first, but if the rain is long continued they diminish. I cannot give the hourly figures.

23196. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—The intercepting sewers were laid from 15 to 22 years ago; the ordinary street sewers were laid any time within a century. There has been no material sinking, the ground being very firm.

23197. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times? Please state whether in making the analysis the solids were removed by settling or by filtering through filter paper?—The following are average analyses of the liquid during eight storms in 1904:—Suspended matter at commencement of storm, 76·6 parts per 100,000; after one hour's duration, 78·6 parts; after 3½ hours' duration, 41·6 parts. Oxygen absorbed in 4 hours at commencement of storm, 12·3 parts per 100,000; after one hour's duration, 3·4 parts; after 4 hours' duration, 3·6 parts. I have given the average analyses of the sewage in summer and winter in answer to a previous question. In making the analyses the solids were removed by settling.

23198. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm? I should be glad if you would state your views fully on this question, and if you would also tell the Commission what number of dilutions you think it practicable to treat in one or another way?—Our sewage works are arranged so that four times the dry weather flow could be dealt with by the ordinary tanks, roughing filters, and bacteria beds, the latter working for 24 hours without intermission. In dry weather the beds would work in the proportions of one hour's work and three hours' rest. I think that in our case the best provision for storm flows would be large reserve tanks to hold (say) one day's storm flow, which might pass through the ordinary works during the following days. I do not approve of special storm filters, seeing that unless in constant use we could not expect the multitude of bacteria to be ready for such irregular duty on a large scale.

23199. What shape and size are your storm overflows?—The storm overflows are in several places of sectional area about equal to the sewers they serve. The main ones have sills of about 22ft. in length, so as to require only a moderate rise for a full discharge.

23200. Would it be possible to have a standard form of overflow?—That would not be possible in our case.

23200.* Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—No.

23201. Should storm overflows be fixed or movable?—They should be fixed.

23202. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case?—Certainly; I think the storm overflow should depend on the circumstances. Our Ship Canal, for instance, is a much less injurable outfall than a fish stream would be.

23203. Could you give us an analysis of a typical sample of your road water during the early period of a storm?—No, I cannot do so.

23204. Have you any information as to the bacteriological condition of the road water?—No.

23205. Do you consider that in certain circumstances this liquid should be purified?—Yes.

23206. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers? Initial outlay as well as annual cost should be borne in mind?—I think the separate system has great advantages for all scantily populated areas, but for town areas the combined system is always preferable, and in each case economy would be best attained by these different systems.

23207. Is your sewage settled, and if so how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—The sewage passes continuously through a screen fitted with automatic rakes, and is then pumped into a mixing chamber, where it receives the milk of lime. After mixing with the lime it passes along a channel to the precipitation tanks, on the way receiving a solution of copperas. It then passes slowly through precipitation tanks, taking about three or four hours to pass through the tanks. The following is the average analysis of tank effluent for years 1903 and 1904, in parts per 100,000: Oxygen absorbed in four hours, 4·7; alkalinity as CaO, 3·0; suspended matter, 2·9; free ammonia, 1·95; albuminoid ammonia, ·448; nitrogen as nitrates and nitrites, ·172; chlorine, 14·1.

23208. Have you data to show what proportion of the suspended matter in your sewage is settled in ½-hour, 1, 2, 3, 4, 5, 6, 12, and 24 hours, if the sewage is given quiescent settlement?—The average results of 25 samples taken from the tanks are, immediately after filling, 11·4; after two hours' rest, 7·1; after four hours' rest, 4·4; after 12 hours' rest, 3·6; after 14 hours' rest, 3·6.

23209. What time would be necessary for you to gain a good tank liquor containing, say, no more than six or eight parts of suspended solids per 100,000 from your sewage (without the addition of chemicals), (1) by quiescent settlement, (2) by continuous flow settlement?—The sewage of Salford cannot be purified without chemicals.

23210. Do you prefer to use settlement tanks in series or in parallel?—In parallel.

23211. In the case of continuous flow tanks do you think there is any advantage in the employment of baffling boards or walls?—Yes.

23212. How is the *sludging* of tanks done at your works, and what is the character of the sludge? Does any nuisance attend the operation, and, if so, is it serious? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from your tanks?—The tank liquor is run back into the sewer till the surface of the sludge is exposed. The sludge is then run into storage tanks holding between 3,000 and 4,000 tons, and remains there until sent to sea by steamer. There is no other means of storing the sludge.

23213. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—We arrest the road detritus in silt pits before the sewage enters the tanks.

23214. What is the manurial value of your sludge, and will farmers take it?—Practically speaking, it has no manurial value. The farmers will not take it.

23215. Are there any chemical poisons in it?—Practically, none.

23216 Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—We do not find any nuisance, and no complaints have been made.

23217. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by sewage through septic tanks?—The Salford sewage is best precipitated by chemical treatment.

23218. Have you tried various chemicals? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—We have tried many systems of sewage purification, and combinations of chemicals. The best and most economical results have been obtained by the use of lime followed by salts of iron.

23219. What is the most effective way of adding chemicals?—By adding the lime as milk of lime and the copperas afterwards, in solution.

23220. What is the character of the suspended matter in the liquor from your precipitation tanks?—Organic matter, 47·2; silica, 10·1; iron oxide, 15·8; alumina, 3·4; lime, 12·2; copper, 1·1.

23221. Do you find it necessary to add further chemicals to the sludge before it can be dealt with?—No; the sludge is sent to sea.

23222. Have you had any experience with septic tanks?—No.

23223. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to? Kindly give the figure in parts per 100,000?—Yes; I consider 1·5 parts per 100,000 a practicable limit.

23224. How do you consider that this can best be done?—By passing the sewage through roughing filters consisting of three feet in depth of gravel.

23225. Have you any experience of any mechanical device or any special tanks for freeing tank liquor if suspended matter before delivering it to filters?—Yes. We have for many years tried experiments with roughing filters formed of graded gravel and coarse sand, and have found it practicable to remove about 75 per cent. by these means.

23226. What other, if any, method of dealing with tank liquor before delivering it to filters do you regard as necessary or advisable?—I do not consider that anything else is necessary.

23227. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement?—We have tried many experiments with settling tanks, and though various systems sometimes produce almost identical results, I think the balance is slightly in favour of continuous flow rather than quiescent settlement. In a given size of tanks precipitation with chemicals is certainly much more efficient than settlement without chemicals, either for producing good tank effluent or as a preparation for aerated filter beds. I speak of our own case, where sludge can be disposed of by shipping to sea at about 9d. per ton.

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23228. With regard to contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—We have not used contact beds at our Salford works.

23229. Can you tell us whether, within certain limits, the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—I think that the limits of depth should be from 4 ft. to 8 ft.

23230. What do you consider is the most convenient size for a contact bed?—Five feet deep.

23231. What do you consider to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is, in your experience, the least disintegrable in a contact bed?—Crushed clinkers about a quarter of an inch in diameter.

23232. What size should the filtering material be, and should it be graded in the beds?—Three-quarters of an inch graded to one foot of two inches at bottom.

23233. How should the bottom of the bed be contructed?—With perforated tiles.

23234. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—Yes.

23235. Have you had any experience of the working of contact beds?—No.

23236. With regard to continuous or percolating filters, what do you find are the best filtering materials, and what size should the material be?—Clinkers, 3-16 to $\frac{3}{4}$ inch.

23237. What depth should a percolating bed be to obtain a good effluent?—Five feet.

23238. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?—Yes.

23239. Is the material better disposed in the form of two beds, to be fed in succession with the same liquid, or in one deep bed? --In two beds, one roughing and the other final.

23240. How should percolating filters be fed?—By mains or jets from the roughing filters.

23241. Should the feed be intermittent or continuous? —Intermittent; working two hours and resting two hours.

23242. What is the best form of distribution? What, in your opinion, are the conditions which have to be fulfilled by a perfect distributor, having regard not merely to the distribution of the liquid itself, but also to the purification of the liquid and the life of the bed?—With ample fall available, I prefer distribution by spray jets. Where the fall is limited, I should prefer revolving sprinklers.

23243. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—A constant amount of liquid should be put on the filter. The amount should not be increased in time of storm.

23244. Is there any practical advantage in artificially heating the liquid which is being treated upon percolating filters?—There might be some advantage.

23245. Have you had any experience to show whether open sides are an advantage to a percolating filter?—Yes, they are an advantage.

23246. Have you made any study of the conditions of aeration of percolating filters?—Yes.

23247. What do you consider is the most convenient superficial area for a percolating filter?—With fixed sprinklers on square shaped filters the superficial area is immaterial.

23248. Do you think it desirable that the bottom of a percolating filter be raised from the ground?—Yes.

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23249. Do percolating beds, in your experience, choke? If so, have you been able to measure the rate of choking, and how do you suggest that this choking can be removed, and at what cost?—If properly made, these beds do not choke.

23250. Of what nature are the suspended solids in the filter effluent? How much is organic matter, and are they putrescible apart from the liquid portion of the effluent?—The quantity of suspended solids in the filter effluent is about 1 part in 100,000. Ten per cent. of it is organic matter. It is not putrescible.

23251. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a percolating filter is different from the organic matter of the suspended solids going to that filter?—It is not very different.

23252. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter, and to what minimum figure do you think such settlement or other final treatment can be carried as a practical measure?—The amount of suspended matter is insignificant.

23253. Do you find that the suspended solids in your filter effluent vary much in amount from time to time, and, if so, can you explain the causes of such variation?—No, it does not vary very much.

23254. What was the cost of your percolating bed installation per acre, and how much liquid do you treat per acre, per 24 hours, at ordinary times and in storm times? Please give the depth of the filter and an average analysis of the liquid which you put on and an average analysis of the effluent when working at the ordinary rate and when working at a greater rate in storm times. In each case I should like you to give the figures for suspended solids, if you have them?—The cost was about 22s. per square yard. The filters are 5 ft. deep. The average analyses of the tank effluent going on the filters and of the filtered effluent are:—

	Tank Effluent.	Filtered Effluent.
	Parts per 100,000	
Four hours oxygen absorbed	4·7	·69
Free ammonia	1·95	·60
Albuminoid ammonia	·448	·127
Nitrogen as nitrates and nitrites	·172	1·651
Suspended matter	2·9	·86
Chlorine	14·1	13·6

23255. Have you made any experiments which throw light on the action of percolating filters, with regard to the oxidation of (a) the ammoniacal and organic matter in solution, and (b) the organic matter in suspension?—No.

23256. Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter, or that they are first absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one?—I have no evidence on this point.

23257. Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter?—No; but I think the higher the temperature the better is the effluent.

23258. Have you found any trouble from vegetable growths in percolating filters? If so, have you been able to form any opinion as to the causes of these growths and as to the way in which the growths can be prevented?—We have had no trouble with our filters.

23259. Do you find any nuisance from the treatment of sewage on percolating filters? Have any complaints been made?—No. Now and then in hot weather there may be a little odour.

23260. I gather that you are unable to give any evidence as to the comparative cost and relative advantages of percolating filters and contact beds?—I have had no experience with contact beds.

23261. Have you had any experience of storm water filters?—No.

23262. Have you any practical suggestions to make for disposing of sludges?—In our case all sludge can be most cheaply disposed of by shipping to sea. Under other circumstances I should advise the use of destructor furnaces.

23263. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?—Yes.

23264. What, in your opinion, constitutes a good effluent?—One that does not undergo secondary decomposition, and which will not injure the stream into which it is run.

23265. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—Oxygen absorbed from permanganate in four hours, and incubation for seven days from 70° F. to 90° F. If the effluent absorbs much oxygen in three minutes and four hours, it will certainly dissolve the absorbed oxygen from the steam into which it is discharged, and in this way have a polluting effect.

23266. Have you tried the "aeration" test, *i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—Yes, and I think it a very good test.

23267. Is one standard for all effluents passing into non-potable streams possible and desirable, and, if so, what should it be?—Yes. I consider the standard adopted by the Mersey and Irwell Joint Committee to be a good and desirable one.

23268. What amount of suspended matter would you allow in an effluent, and what are your reasons?—From 1 to 3 parts per 100,000. I have come to this conclusion after much experience.

23269. What is your experience of the effect of storm water upon filters of various sorts?—I have had no experience of that.

23270. How far do you consider it advisable for a sewage installation to be worked automatically?—Automatic working is preferable.

23271. Have you made any systematic observations as to the effects of discharging effluents of known volume and known composition into ditches, canals, brooks, or rivers of approximately known volume?—No.

23272. Could you make a short statement setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents, and giving your reasons?—The absorbed oxygen and the albuminoid ammonia tests are, I consider, quite sufficient.

23273. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—According to the amount of chemicals it requires to purify 1,000,000 gallons.

23274. I would just like to ask on Question 23173 how are the contents that come from the pail closets and middens disposed of?—They have got a refuse destructor. The greater part of the refuse is taken to this destructor and burned.

23275. Is it taken by municipal authority?—By municipal authority; yes, by carts.

23276. And destroyed as refuse by a destructor?—As refuse.

23277. And that is probably done without any nuisance at all?—Without any nuisance.

23278. On Question 23186, the figure 564·3 parts per 100,000 seems very large; was there any exceptional reason for it?—It is simply this, that sometimes the sewage gets very low and the pumps are working and pumping up the sludge. It is only now and then that that occurs.

23279. (*Sir William Ramsay.*) A comment strikes me as regards your answer to Question 23175, that the maximum dry weather rate of flow is 14,000,000 gallons per day about 3 p.m.; is that not rather a late hour for that; generally it is earlier in the day?—We always notice that there is more just about that time.

23280. Is it explained by trade effluent or something of that kind?—Oh, yes, trade effluents; of course, that does not apply to Sunday.

23281. In answer to Question 23184, you say that no rules are enforced; are there any rules framed; is no attempt made to enforce them?—No, not any particular rules; of course, if we know that there is any very great amount of solid matter going into the sewers, we stop it, because we make the manufactnrers have a catch pit, and we have arranged that the corporation shall empty these catch pits and take away the sludge free to the manufacturers.

23282. You say you make them put in a catch pit; that sounds as if there was some rule after all?—Well, I do not think it is a hard and fast rule exactly.

23283. It is simply that you have come to an arrangement with the manufacturers?—With the manufacturers; they are, I believe, more obliging, because we have offered to take this solid matter away free of any expense to them, and I think it is more because of that that they have agreed to do it.

23284. Question 23187 deals with the composition of the solids; you have 12 per cent. of oxide of iron?—Yes, Sir.

23285. The Manchester sewage I think has 18 per cent., does that come from pickling works?—No; of course we use copperas sulphate of iron for the precipitation.

23286. It is your own sulphate of iron?—It is our own sulphate of iron, yes.

23287. Are there pickling works in Salford?—No, I do not think so.

23288. So it is all your own adding?—All, yes.

23289. You say that the strength of sewage as affecting purification is best expressed by stating the percentage of purification derived from the oxygen test; which oxygen test; permanganate?—Yes; the four hours test.

23290. Not the absorption of oxygen?—No, no; the permanganate test.

23291. Have you tried the absorption test?—Yes, I have tried it.

23292. Do you think it gives good results?—Yes, very good results; indeed the only reason we keep to this oxygen test is because the Mersey and Irwell Joint Committee always use it; so we have agreed to do it according as they do it; that is why it is done.

23293. In answer to Question 23198, towards the end, your reply strikes me as somewhat conjectural; I should like to ask if you have practical experience of the working of storm filters. I mean, for example, you say "In dry weather the beds would work .... I think that in our case the best provision would be large reserve tanks;" it sounds as if you had no practical experience; have you had any?—No, the works are not completely finished, and whether the Corporation are going to put up the storm filters is not known, but our engineer says that the filters that we have got down now are sufficient to deal with the storm water.

23294. Yes; so that you have not any actual experiments to deal with this subject?—No, not actual experiments.

23295. To Question 23200* you answer "No." It is a very short answer to rather a long question; have you any reasons to give?—Well, I could not say I have got any experience on that.

23296. In answer to Question 23206, you state that the separate system has great advantages for all scantily populated areas; and for town areas the combined system is always preferable. Could you explain that a little; give your reasons why?—Well, the only thing I should say about the town system is because of the enormous expense it would be to make any alteration now; they could not make any alteration at the present time in Salford; they could not possibly do it.

23297. That is all?—That is all.

23298. It does not mean that the ideal state of things would not be a separate system of sewers for the towns, but merely the practical fact that the towns cannot stand the expense?—No, those who have got a sewage works or a drainage laid out now could not.

23299. In answer to Question 23209 you say, "The sewage of Salford cannot be purified without chemicals." Is that the result of experiment or of general opinion?—No, that is the result of experiment.

23300. Can you give the reason why it is so?—Well, because we have so much dissolved impurity in the sewage and we tried for a fortnight, especially a fortnight without chemicals at all, and of course the effluent was not fit to run into the Ship Canal.

23301. That is after mere sedimentation?—That is after mere sedimentation, passing through the tanks.

23302. You have not tried septic tanks on the sewage?—No, we have not; on our own system we could not do it.

23303. That means that chemical precipitation is better than sedimentation?—Yes, but what we do think is this, that if we were not to put so much effluent on our filters, and were only to put half or quarter the quantity, we think we could do without the chemicals; but at the present time our filters are not large enough to take it.

23304. Have you a reason why you prefer to use settlement tanks in parallel—in answer to Question 23210?—No, it is simply that these tanks were built about 20 or 25 years ago, and economy of room.

23305. What composition has your sludge?—I give it.

23306. You say that farmers do not take it?—Well, to begin with we have tried it upon ground of our own and it does not seem to answer; our manager has got a very large garden there and he will not use it; he says it destroys everything; he cannot grow anything there, and we have no farmers in the neighbourhood that would come and take it away.

23307. Is that due to the presence of copper? In answer to Question 23187 you put down 1 per cent. of copper, which is very high?—That is on the dry sludge.

23308. That is true, but still it is very high, is it not?—It is rather high; I do not say that occurs every day; we are not, of course, analysing the sludge every day; I have the samples taken and an average sample; and we have got some very large dye works in Salford that use about, I think, a 1,000,000 gallons of water, and I think this copper comes from them.

23309. Do you think the presence of copper is why it does not act as a manure?—No, I do not think it has anything to do with it; it is only this, that the amount of nitrogen is so small and the amount of phosphoric acid is so small; and then we have no means of drying the sludge either; the farmers will have to take it away with 90 per cent of water in it.

23310. In answer to Question 23215, there are practically no chemical poisons in it; you exclude copper, I suppose. because there it is?—Yes, because I do not consider that belongs to the category of poisons: it is only when we have analysed that we have found these traces of copper.

23311. Is there any arsenic in it?—Well, that we have not gone into.

23312. Are there any houses near your works?—Oh, yes, one side, surrounded with houses; well, there are houses within a quarter of a mile.

23313. No complaints have come to you from the houses?—About sewage works?

23314. Yes?—Well, I would not like to say no complaints, because we have a vast amount of sludge there and certainly there is an odour from the sludge; but now there are tar works close to our sewage works and they make really a worse smell than the sewage works.

23315. In answer to Question 23223, you say that you can manage to get the suspended matter down to 1·5 parts per 100,000; that is a very low figure?—That is the suspended matter; oh, yes, we are getting that down. I have got some experiments here; we are just trying a special set of experiments now, and the suspended matter is 1·8.

23316. It is very low?—And 1·3. We are just trying also a special set of experiments for the settlement of the suspended matter, and we are giving a month to each trial, and I have got some results here where the average suspended matter for the month has been 2·4; 3; 2·3; 2·9; 5; and 2·6.

23317. Very low on the whole. What is your precipitant; I do not remember?—Lime and copperas.

23318. And a very large amount of copperas?—We use about five cwts. to the million gallons.

23319. And then I presume the copperas oxidises before you have done with it. Is there enough dissolved oxygen in the sewage to oxidise the copperas?—No, we add lime to it to precipitate it.

23320. But the ferrous oxide, is it oxidised before it reaches the filters?—Oh, yes.

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23321. Wholly oxidised ?—Yes, I may say we do not find any iron in the effluent after what I call the tank effluent.

23322. And is it a yellowish precipitate or greenish ?—No, yellowish ; it is the ordinary oxide of iron.

23323. It is all ferric, in fact ?—Yes.

23324. How often do the roughing filters to which you allude in Question 23225 require cleaning ?—Well, every two or three months. I may say that is the *bête noir* of the system. We find more difficulty with these roughing filters almost than anything we have got to deal with ; these roughing filters gradually get blocked up and will not filter enough of the sewage to go on to the final filters ; and then the gravel, etc., has to be taken out and well washed. That ought to be done every three or four months.

23325. Then these roughing filters come before your chemical precipitation ?—No, after.

23326. After the chemical precipitation ?—After ; the roughing filters come after the effluent has passed through all the tanks.

23327. Then in answer to Question 23232 you give the size of the filtering material ; that is very fine ; I suppose you regard the roughing filters as having made it possible to use such fine materials for your subsequent filtration ?—Yes, it has.

23328. There are several questions : 23236, 23237 23238, and so on ; you give answers to the questions, but do not base the answers on any statement as regards experience. May I just go through these ; have you tried any other material besides clinkers ?—Yes, we have tried coke ; but, of course, we have had this polarite down there ; we have tried that and various things.

23329. Is the clinker the refuse from the destructors ?—Yes, it is. Of course, it is clinkers that we use ; we take it from anywhere ; the destructor would not supply us with the quantity that we require, so we are obliged to contract with people at so much a ton to bring their cinder to us ; then we take these clinkers and we bring them up and grade them, sift them, and so on, and then put them into the filter.

23330. Have you tried percolating beds of different depths from 5 feet ?—Yes, we have tried 1, 2, 3, 4, 5, and 8 feet. At the present time the majority of our beds are 5 feet, and we have got two special ones of 8 feet ; and of course we find the 8 feet give better results than the 5 feet ones.

23331. But not proportionately better ?—Well, if you will allow me : I have got a report here upon that very question. It is a report I made to the Corporation ; a comparative report upon two experimental filters, the 5 feet and the 8 feet ; I say No. 1 filter was filled with 5 feet of cinders, No. 2 with 8 feet ; the object of the experiment was to ascertain which would give the best effluent after passing the roughing filters and the final filters. The two filters were worked for 23 months. The standard of purity is that 100 gallons should not require more than 100 grains of oxygen to oxidise the organic matter ; of course that is one grain of oxygen ; therefore the standard is 100 ; or in other words, all effluents above 100 are not good ; and below 100, the lower the number the better is the effluent. Thus, for example, the effluent which has a number of 30 is better than one of 60, and the latter is better than one of 90. The following figures give the daily average number of oxygen required for four hours for each month, the filters having been worked daily.

Five-feet Filter. Oxygen in grains for 100 gallons	Date.		Eight-feet Filter. Oxygen in grains for 100 gallons
114	May	1900	57
109	June	,,	79
125	July	,,	127
112	August	,,	113
63	September	,,	54
61	October	,,	45
145	November	,,	103
152	December	,,	111
Then in 1901 :—			
126	January	1901	108
189	February	,,	149
187	March	,,	172
90	April	,,	83

Then in May and June the filters were stopped for cleaning, and then we jump from April to July. Now, this is after the filters have been cleaned :—

Five-feet Filter. Oxygen in grains for 100 gallons	Date.		Eight-feet Filter. Oxygen in grains for 100 gallons.
66	July	1901	61
68	August	,,	58
70	September	,,	86
70	October	,,	71
61	November	,,	73
83	December	,,	77
93	January	1902	62
124	February	,,	79
147	March	,,	88
107	April	,,	63
147	May	,,	83

The average number for the twenty-three months is :—109 for the five-feet filter ; 87 for the eight-feet filter. It must not be forgotten that in the early days of the filters, the five-feet had more work to do than the eight-feet filter. Thus, in May, 1900, the five-feet filter had considerably more effluent passed through it than the eight-feet. This was altered in July, 1900, when the eight-feet was made to work sixteen hours against ten hours for the five-feet filter. Certainly the eight-feet does show a better effluent in the average than the five-feet, but the question is whether the eight-feet is worth the extra expense. I think not. My opinion is, that it would be better to make extra filters and pass a less quantity of effluent.

23332. You appear not to have worked the filters quite continuously ; you gave them periods of rest each day ?—No, the way we work them now is, two hours work and two hours rest.

23333. It is still continuous filtration ; it is not contact filtration ; you do not fill the beds and empty them ; but you let the liquid drip through ?—That is it ; of course we have something like about sixteen to eighteen filters ; then one is working while the other is resting, and so on alternately.

23334. But do you not find it is sufficient to allow the air which is carried through by the percolation to act ; would that not be sufficient ; must you rest your filters, because many percolating filters go on continuously day and night ?—Yes, we had some about three or four years ago working without stopping at all ; but they were eight-feet filters, and they answered admirably ; but our manager seems to think that it is a better way to let them rest.

23335. Is it customary to let them rest ; I do not remember that filters of this kind are used intermittently : I may be wrong ; perhaps Mr. Willis will know ?—I think there is generally a period of rest ; but ours spray—just like a fountain ; we have got fountains—and it sprays it all over the filters.

23336. (*Secretary.*) I should say it is somewhat exceptional, the way they are worked at Salford. (*Mr. Frye.*) It is usual to give a period of rest going through fine material.

23337. (*Colonel Harding.*) I was going to suggest the reason of the exceptional treatment at Salford is because you are using very fine material ?—Yes.

23338. And you find in practice that if you continue to feed at the rate you do for more than two hours you get pooling on the surface ?—That is it.

23339. And you are obliged to interrupt and allow what is in the filter to drain off and go on again ?—Yes.

23340. That is a circumstance due to the special character of the material ?—Yes.

23341. (*Sir William Ramsay.*) Then that again shows the reason for your answer to Question 23243 : "A constant amount of liquid should be put on the filter, which should not be increased in time of storm." I suppose you cannot do it ?—You mean we cannot put more on the filter ?

23342. You would pond your filters if you tried to increase it ?—We are increasing the filters, making more filters.

23343. I mean, supposing you tried to feed each filter with a larger quantity of effluent ?—We find it does not answer; the oxygen test goes up directly if we put too much on.

23344. And do the filters pond ?—Yes, what we call pool.

23345. You speak of open sides as being an advantage to a percolating filter. Have you any experiments to test this ?—No, I cannot say that we have done so, but we went to see some at York where they had open sides; the Committee went there, and they told us that they were a very, very great advantage, the open sides; but ours are not open sides.

23346. Were they some small filters at York ?—No, I should not call them small; they were circular filters. I should think 20 or 30 feet across.

23347. Have you ever estimated the oxygen in the interior of these percolating filters of yours or not ?—No, we have not.

23348. You do not know whether the oxygen is fully absorbed ?—No.

23349. You stated in answer to Question 23249 that if percolating beds are properly made they do not choke. What do you mean by properly made—properly graded ?—Properly graded, yes; you must not have a lot of very fine stuff in it.

23350. And you are referring to a well-settled chemical effluent ?—Yes. Well, our No. 1 and No. 2 filters I should think have been in use now for three years, and we find they work just as well now as they did the first day they were put down.

23351. How do you test for putrescibility in the liquid portion of the effluent ?—The incubation test.

23352. And you find it is not putrescible ?—No.

23353. The answer which you have just given me and the answer to Question 23251 look a little contradictory: "the suspended solids issuing from the effluent of the percolating filter are different from the organic matter of the suspended solids going to that filter." The one I suppose putrifies and the other does not ?—No, what comes out of the final filter, the effluent, the suspended matter; well, it contains perhaps rather more organic matter than what goes on. I look upon it that it is merely washing; there is a kind of what I may call a scum of sewage fungus there, and every now and then it seems to wash it out.

23354. Yes, but the point is this. Supposing you were not to filter your chemical effluent, would it putrify ?—Oh yes, it would; oh, it would indeed.

23355. But then surely that would show that the suspended solids in the one case are different from the other ?—Of course, there is the soluble organic matter.

23356. You think it is that that putrifies; not the solids so much ?—I do not think the suspended matter has anything to do with it.

23357. How do you distribute on the filters ?—By the spray; what we call the spraying jets.

23358. Do they rotate ?—Oh no, they do not rotate; it is simply a lot of iron pipes cover the filters, and at distances of about perhaps two feet there is a little jet like a fountain, and then it sprays all over it, just like you water a lawn.

23359. Do the holes not stop up ?—No, we have not found them do so.

23360. You say you do not require special treatment ?—No, we have worked these for three years, and we have no trouble with them.

23361. Have you much head ?—About four or five feet. Oh, we have had no trouble at all with the stopping up of the holes.

23362. I suppose you think the Mersey and Irwell standard is a good enough one ?—I should consider very good indeed.

23363. You do not wish it to be altered ?—We conform to it with our filtered effluent; our filtered effluent is generally about half a grain of oxygen.

23364. In answer to Question 23268, you suggest from one to three parts of suspended matter might be allowed in the effluent per 100,000, and you have come to this conclusion after much experience. Could you give us the kind of experience ?—Well, the experience we have got from our final effluent which passes into the Ship Canal; there is always some fine sediment in it. I do not think it is possible that you could produce a filtered effluent, and a good effluent, without some small suspended matter.

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23365. And you consider that amount is of no consequence ?—Oh, I do not think so at all.

23366. Is your filtration automatic; do these sprinklers go on of their own accord, without any attention ?—Oh no, they have to be attended to; the man has to turn the effluent on for several hours.

23367. At considerable intervals you run them off ?—Two hours, and two hours rest.

23368. That, of course, could be done automatically if you wished ?—And it is in some places done automatically.

23369. Do you find that the albuminoid ammonia test gives the same result as the oxygen absorbed test with your effluent ?—Yes, it is generally about 0·1 in the 100,000, and even sometimes a little less, but it is generally about 0·1.

23370. And they run parallel ?—They run parallel, and then the oxygen we expect to find about 0·5 to 0·6; I should expect to find it.

23371. Really they are the same test, are not they. The estimation of albuminoid ammonia involves the use of permanganate, and it is all one whether you estimate the ammonia that is produced or the permanganate that is used; is it not so ?—Do you mean it is the same test ?

23372. Really the same test, because in both cases you employ permanganate; in the one case you estimate the ammonia which is distilled over, and in the other case the permanganate which is used up ?—Yes.

23373. They do not always run together, but in your case they appear to run together ?—Practically speaking, of course I should be very much surprised to find a high albuminoid ammonia and a very low oxygen; I should be very much surprised; in fact I hardly know of such a thing.

23374. Would that not shew that there are no reducing agents in your sewage ?—Exactly so; oh, yes. There is this to be said, that sometimes we get a little tarry matter into the effluent, such as a little carbolic acid, and of course it raises the oxygen test at once; and that is why it is not always safe to go upon the oxygen test, and it would not be right to condemn the works simply because the oxygen test was very high without looking further into it. I know I have had a case from Redditch—I think Calvert's works are there—where the effluent is generally very high in oxygen, but that is due just to a little carbolic acid.

23375. And of course that would not be shewn in the albuminoid ammonia test ?—It would not be shown; no.

23376. Your suggested measure of the strength of a sewage or tank liquor is unusual; "the amount of chemicals which it requires to purify 1,000,000 gallons." That, I suppose, is based on your own special experience ?—Exactly so; the more chemicals, of course, that are used, the better effluent you can get.

23377. Have you been experimenting on the amount of chemicals required; have you varied that from time to time ?—Yes, we have tried that for ten or twelve years.

23378. And you are working with less quantity ?—We are working with less quantity.

23379. (*Major-General Carey.*) The dry weather flow, based on water supply for all purposes, is 4,630,000, your population 231,000, and your number of gallons of water supply per head is estimated at 20 gallons, 15 for domestic and five for trade ?—Yes, that is right.

23380. Based on water supply, the dry weather flow works out at 4,630,000 ?—Exactly so.

23381. But your recorded flow is 8,000,000—Question 23174 ?—Yes.

23382. The dry weather flow that has got to be pumped up to the works amounts to 8,000,000 ?—Exactly so.

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23383. And the difference is considerable, 3,369,000 gallons per diem; is that due to subsoil water?—No, it is due to works; we have got one works in Salford that I believe run a million gallons a day into the sewer—one works alone.

23384. I do not quite understand; how do you make up the difference? You have got three millions and odd gallons to account for?—Of course there will be subsoil water, and these works that I speak of that send in; it is a most difficult thing to gauge the quantity from these works—a most difficult thing.

23385. (*Sir William Ramsay.*) Have they private wells?—Yes, private wells.

23386. (*Major-General Carey*). Question 23198; have you formed any estimate as to the probable cost of providing large reserve tanks to hold, say, one day's storm flow?—No, I have not done that, but it would be something very, very great.

23387. Would it be very considerable?—Very considerable. I do not think our Corporation would entertain such a thing at all.

23388. At the same time you think it would be the best provision to make?—It would be.

23389. As to the distribution of the tank effluent on the beds at Salford, is any nuisance caused by such a distribution?—I cannot say exactly there is very, very much nuisance. In warm weather there is certainly rather what I may call a strong odour of a peculiar kind, what I may call a sewage odour, from the spraying, but I do not think it reaches very far.

23390. Have the sprinklers ever been affected by frost?—Never.

23391. Have you ever had sufficient frost to test them?—Well, we have worked those sprinklers for three years. Of course this last winter has not been what I call a very hard winter, but still we have had three years you see.

23392. The warmth of the sewage is sufficient to counteract the colder weather?—Exactly; we have never had any difficulty from frost.

23393. Question 23230; it is not quite clear to me why the depth of 5 feet is regarded as the most convenient for contact beds. Have contact beds of 3 to 4 feet in depth ever been tried experimentally in Salford?—Well, of course we call ours filters, do you see.

23394. Well, filters?—Yes, filters. Yes, we have tried one foot, and two, and three, and four, and five feet, and we find that the five feet gives us as good results as any we have done.

23395. Or better results?—Better results than one, and two, and three feet.

23396. One foot of course, is very shallow, but a three feet or four feet filter?—Yes, better than that.

23397. Because the deeper the filter the more expensive it is?—Yes, exactly so; we have got two of these filters at 8 feet, and they give certainly better results that the 5 feet; the two at 8 feet deep give us better results than the 5 feet.

23398. You say, of course, the limits, the permissible limits, should be from 4 to 8 feet?—Then I go about expense.

23399. You would put a 3 feet bed out of consideration altogether?—Well, I should not put it out of consideration. If you would put less effluent upon it you would have to put, say, a quarter of the effluent, or half the effluent, that you are putting on the 5 feet bed.

23400. (*Colonel Harding.*) Might I ask you, on the point that you are just now answering about the depth of beds, whether you have made any experiments to show that with a flow proportional to the depth you get better results with 5 feet deep than from 1 foot deep; in other words, suppose you had a bed 2 feet deep, and you passed through it only two-fifths of what you passed through a bed 5 feet deep, would you get similar or better results, or worse results?—What I understand is, if you pass one-fifth of the effluent through a one foot filter, would you get the same results as passing five times the quantity through the 5 feet filter?

23401. Would you get the same, or a better, or a worse result?—I have not gone very much into it, but I should say you would get about the same if you only lessened the test; in our case if you had 1 foot filters you would have to extend the area so very, very much.

23402. But in saying that you get better results from the 5 foot filter than the shallower filter, did you mean at the same rate of flow?—At the same rate of flow.

23403. But that you would naturally expect, would you not?—Yes, but sometimes we get almost the same result through the 5 feet as we do with the 8 feet.

23404. The question of the depth of the filter must be regulated largely by the question of levels, must it not?—Yes.

23405. If you have only a shallow depth, then you must feed the effluent more slowly through the filter? Exactly so; yes.

23406. But speaking broadly, at an equal flow you get better results from a deeper than from a shallower bed?—Yes.

23407. I should like to ask you how you account for the considerable difference which exists between the water supply per head in Salford, which you tell us is 20 gallons including all that is used for trade purposes, and the amount of dry weather flow sewage which comes to your works, which works out at 34 gallons per head?—Yes, it is put down, of course there is a large quantity of subsoil water.

23408. Is that sufficient to account for that large difference?—Yes. I have heard it generally said, taking into account the trade effluents, the water that is used in the manufactories.

23409. In telling us that your water supply is 20 gallons, that includes, I believe, 15 gallons per head used for domestic purposes and 5 for trade purposes; that is 20 altogether?—Then of course there are the works that have wells of their own, and pump their own water. That does not apply to them.

23410. Does that account for an important volume of water?—Well, as I have just said, there is one works that gives a million gallons a day.

23411. Your explanation of the difference is that it is due to subsoil water and independent sources of supply by private firms?—That is it, yes.

23412. The amount of sewage that comes to your works during the year is 3,355,000,000 gallons, you tell us in your answer to Question 23181?—Yes, that is so.

23413. That is not greatly in excess of your dry weather flow; only slightly?—No.

23414. I find that taking your dry weather flow at 8,000,000 gallons per day, that works out at 2,920,000,000 gallons; and what comes to the works, the maximum is 3,355,000,000; so that you are not receiving at the works much more than your dry weather flow?—At the present time we have no means exactly of checking the storm water that comes.

23415. It is evident that you do not receive much, because you see the maximum which is received at the works during the year is only slightly in excess of the dry weather flow?—Yes, that is so.

23416. Is that because your mains are not large enough to bring it, or is it because you discharge it by storm overflows?—We have got storm overflows that go to the Ship Canal; they do not come into the works at all.

23417. Is there any proposal on the part of your Corporation to deal with these storm waters?—Yes, I believe at the present time, I think practically speaking there is nothing goes into the Ship Canal now; we are using the whole of it, but I could not say in the case of a heavy storm that we should filter the whole.

23418. I am afraid I did not understand your answer; you say you are using the whole of it—the whole of what?—The sewage that comes to the works.

23419. But, then, that is so slightly in excess of your dry weather flow that you cannot now be treating storm waters at all?—No, the storm water would pass by the overflow.

23420. Does your Corporation propose to treat storm waters?—Yes, I think they do; I think they intend doing so—that is why they are extending the filters.

23421. What is the intention, then; is the intention to pass the increased flow through the precipitation tanks and then pass it over the filters?—Exactly so, I may say that even now we are just erecting a pump that will lift, I believe, something like 25,000,000 gallons a day.

23422. That would be about three more volumes?—Yes, and we have got two pumps now that lift somewhere about 10,000,000 or 12,000,000 gallons a day, so that we shall be able to deal with the storm water overflow.

23423. Well, we should be interested to know in what way you propose to deal with these storm waters?—Just in the same way as we do now; through the tanks, through the rough filters, and even then through the final filters.

23424. Do I understand that during time of storm the flow through the precipitation tanks will be considerably increased?—Exactly so.

23425. Do you anticipate any difficulty from that?—No, we do not, because that is why we are putting down this pump.

23426. And you expect you will be able to increase the flow through your precipitation tanks to the extent of five more volumes?—Yes.

23427. And that you will not injure the results?—We will not injure the results, no; we are extending the filters.

23428. Let us confine ourselves for the moment to settlement tanks. Do I understand you to express the opinion that you may increase the flow through the precipitation tanks six times without injuring the results?—Yes, because there will be so much storm water with our ordinary effluent that it will weaken it very much indeed. If you have got a quantity of rain water that you mix with the effluent, it must reduce the impurity very much.

23429. I am to understand that you think the storm waters will be sufficiently dilute to permit of such rapid flow?—Yes, that is it.

23439. Without getting a bad result at the end?—Exactly so.

23431. Would you largely increase the amount of precipitants used?—No, I do not think it would be necessary, because I should look upon it that the sewage would be so weakened that it would not be necessary to increase them.

23432. Possibly it might be at the end of many hours' storm, but you would expect, would you not, during the earlier period of a storm that the sewage would not only not be weak, but probably would be considerably worse than the dry weather flow?—Well, it would be worse in this way, that there would be more suspended matter, and the suspended matter would settle in the tanks as the effluent was passing through the tanks.

23433. But is not the efficiency of settlement due largely to the rate of flow, and if you increase the rate of flow by six, will you not get inefficient settlement?—Yes, you are quite right there, but then we have got ten tanks in all, and we should pass it then through ten tanks, whereas we are only passing through five at a time now.

23434. Tell me whether the opinions you have expressed to us are due to actual experiments or simply surmise as to what you expect will take place after you get your new pumps going?—We have no practical experience.

23435. You have not tried experiments in dealing with dilutions through times of storm with one of your tanks, for instance?—No, but I have analysed the effluent of those dilutions—the suspended matter.

23436. I may take it the storm waters do not reach you at all now, and therefore you have not been able to experiment?—They reach us to a certain extent, but then they pass over this overflow into the Ship Canal.

23437. Without having tried any actual experiments to guide you, you are under the impression that you will be able to pass six times the dry weather flow through your tanks without bad results?—Well, that is the opinion of our manager and engineer, that we shall be able to do it. That is why we are putting down this pump to pump the 25,000,000 gallons.

23438. Well, let us move on to your roughing gravel filters. Would you at times of such dilution pass all that flow through those?—It must go through; it would have no other way; it would have to go through.

23439. You said to Sir William Ramsay you had had a certain amount of trouble with those gravel tanks?—Yes.

23440. I did not quite catch what was the nature of the trouble?—Simply that they will not pass the quantity; they have to pass something like 4,000 gallons.

23441. They get choked?—They get choked.

23442. How often have you to wash them out?—Well, perhaps every four or five or six months.

23443. Do you take the material out entirely, wash it, and replace it?—Take the material out and wash it.

23444. And replace it?—And replace it.

23445. And the cost is by no means prohibitive, is it?—Well, of course it is a serious cost.

23446. But it is a cost which you are prepared to undertake?—Yes.

23447. Now what is the improvement brought about in your results by this process of roughing tanks; in other words, what is the amount of suspended matter in your tank effluent as it leaves the precipitation process, and what is the improvement brought about in it by this roughing gravel process?—Well, these roughing filters remove about 50 per cent. of the suspended matter.

23448. The roughing filters?—These remove 50 per cent. of the suspended matter.

23449. That is to say, that if for instance there are four parts per 100,000 in the precipitation liquor, it would be reduced to two parts after passing through them?—Yes.

23450. You really think that the process of passing the precipitation effluent through gravel filters is worth carrying out for the sake of that improvement?—Oh, it is indeed, because up to the present time we have never had one of the final filters stopped, and if we had passed the tank effluent direct on to the final filters we would have had them stopped up exactly the same as we have had the roughing filter stopped up.

23451. Then the reason really why this additional process of passing through the gravel filters is necessary at Salford is because you have fine material in your filters—Exactly so.

23452. You tell us that in using these filters you work them two hours and rest them two hours?—Yes.

23453. That is absolutely necessary for their efficiency?—Yes, we find from practice that it is so.

23454. When you have been working for two hours the effluent begins to pool on the surface?—Yes, we have tried filtering five or six hours at a time and resting four or five hours; we have tried various ways of filtering; but we have come to the conclusion that the two hours work and the two hours rest is about the best.

23455. Have I gathered rightly from some of your answers, that the way you propose to deal with these storm waters is to work these filters for longer periods during times of storm?—We should have to do it.

23456. What about the pooling which arises at the end of two hours?—I did not say that the pooling arises at the end of two hours; the pooling arises more from the quantity that we put on.

23457. The supposition is that in times of storm you are going to considerably increase the quantity?—But then they are going to considerably increase the area of the filters.

23458. To what extent?—Well, we have just finished two more filters; and they are talking of beginning two more again and two more again; I cannot say exactly—there has been no settled number.

23459. Our object in asking these questions is really to ascertain the practicability of dealing with these large dilutions upon percolating filters such as are used at Salford; and I want to see how far you expect—as I take it you have no experience as yet upon that point—that

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you will be able largely to increase the flow of these fine percolating filters; to what extent you think you would be able to increase the flow?—Well, as you say, of course we have no experience of the storm water; we have never yet used the whole of the storm water; we have had no means you see of doing it.

23460. Are you unable to say to what extent?—I could not; I should not like to say; it would be mere guess work; what we think——

23461. Let me ask you this further; do you think it would be necessary to pass the storm waters over the filters at all if these storm waters have been efficiently settled?—That is just the very point; we do not think it would be necessary, that if we pass it through the tanks and through the roughing filter, we consider that that ought to be enough.

23462. Then you do not anticipate really that you will have to pass the storm waters over these fine filters at all?—Well, I think that they would pass a considerable portion through.

23463. Well, I will leave that point; and I should like to ask you about the suspended matter coming out from these fine percolating filters. I gather that it is very small in amount?—Very small.

23464. But then what goes on to the filter is also very small?—Exactly so.

23465. In the analyses you give us in one of the answers you seem to omit the suspended matter; can you tell us what it is in the effluent going on to the filters; what amount of suspended matter have you?—After passing on to the roughing filter?

23466. Yes?—About two parts per 100,000.

23467. And what comes out from the percolating filter?—About half to one part per 100,000.

23468. Quite a small quantity?—Oh, exceedingly small. But we have to take a large quantity of the effluents really to get any good results with it.

23469. You expressed an opinion in answer to Sir William Ramsay's question that the suspended matter that did come out was largely organic?—A great deal of it was organic matter.

23470. One would be disposed to expect that it would be largely inorganic?—Of course, it varies very much indeed; there is no definite composition about the thing.

23471. But do you not somewhere say that it is only about to the extent of 10 per cent. organic: in answer to Question 23250,—"It is only to the extent of 10 per cent. organic"?—"The quantity of suspended solids in the filter effluent is about 1 part in 100,00. Ten per cent. of it is organic matter;" yes.

23472. Now, did you not rather suggest that the small amount of organic matter, such as it was, was due to the detritus of sewage fungus?—Exactly so, which is a thing which rather varied; we found it on analysis to vary at various times when there has been a large amount of this sewage fungus.

23473. You do not think that such organic matter as there is, is the residuum of what went on to the filter, but is the production of the filter itself?—Yes, it is rather of growth.

23474. Have you paid any attention to this question of growths in the channels of filters?—No, only seen what it is about, the analysis of it; the amount of organic matter in it.

23475. Have you been able to form any opinion as to the wisdom or otherwise of using relatively coarse materials for percolating filters provided you have some subsequent process of settlement; have you tried any experiments in that direction?—Yes, our roughing filters are really what we may call coarse materials; our roughing filters are coarse material.

23476. Yes, but your roughing filters are not percolating filters?—Yes, it passes through; the tank effluent passes through this.

23477. It is streamed through, is it not?—Well, it streams.

23478. They are in effect straining filters?—Straining filters, yes.

23479. But you have not, I gather, tried any experiments at Salford with coarse percolating filters?—No, we have not.

SALFORD.

Appendix to Evidence of Mr. J. Carter Bell.

Tables showing average analyses of sewage, tank liquor, and filter effluents at Salford, January, 1903—December, 1904.

PROCESS OF TREATMENT:

Chemical Precipitation and Filtration through Percolating Coke Beds.

SALFORD.

January, 1903.

SEWAGE.—

Average daily flow	10,688,000 gallons	Rainfall	·078 inches
Maximum daily flow, January 7th	13,890,000 „	Rainfall	·480 „
Minimum daily flow, January 17th	7,025,000 „	Rainfall	·002 „

Average analysis of Sewage - 4 hours, oxygen 4·2

Number of samples analysed for the average - 62

PRECIPITATED SEWAGE.—

Amount of Chemicals added - 13½ cwt. per million gallons lime; 4½ cwt. per million gallons—copperas.

Amount of Sludge dealt with - 8,610 tons.

Average analysis of Tank Liquor - 4 hours, Oxygen, 3·4; alkalinity, 2·5; suspended matter, 4·0.

Number of samples analysed for the average - 62 ·208.

FILTERS.—

Amount treated on Filters during month - 1,033,760 gallons.

Number of hours during which Filters were at work - 208.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - 10·15.

Average analysis of Final Effluent - 3 minutes, oxygen ·33; incubation ·2; 4 hours, oxygen ·67.

Number of samples analysed for the average - 31.

Best analysis of Final Effluent - 4 hours, oxygen ·46; 3 minutes, oxygen ·2.

Worst analysis of Final Effluent - 4 hours, oxygen 1·7; 3 minutes, oxygen 1·0.

All results expressed as grains per gallon.

J. Carter Bell.

February 14th, 1903.

SALFORD—*continued.*

February, 1903.

SEWAGE.—

Average daily flow	10,810,000 gallons	Total rainfall	2·578 inches.
Maximum daily flow, February 21st	16,015,000 „	Rainfall	·590 „
Minimum daily flow, February 14th	7,515,000 „	Rainfall	·003 „

Average analysis of sewage - 4 hours, oxygen, 4·6.

Number of samples analysed for the average - 56.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - $13\frac{1}{2}$ cwt. Lime and $4\frac{1}{2}$ cwt. Copperas per million gallons.

Amount of Sludge dealt with - 6,710 tons.

Average analysis of tank liquor - 4 hours, oxygen, 3·0; alkalinity, 3·0; suspended matter, 3·0.

Number of samples analysed for the average - 56.

220

FILTERS.—

Amount treated on Filters during month - 302,000 gallons.

Number of hours during which Filters were at work - 68.

Rate of filtration (gallons per cube yard of filtering material per 24 hours).

Average analysis of Final Effluent - 3 minutes oxygen, ·26; 3 minutes oxygen after 7 days' incubation, ·19; 4 hours oxygen, ·56; free ammonia, ·23; albuminoid ammonia, ·09; nitrates, ·87.

Number of samples analysed for the average - 28.

Best analysis of Final Effluent, February 23rd - 4 hours, oxygen ·29; 3 minutes oxygen, ·13.

Worst analysis of Final Effluent, February 6th - 4 hours, oxygen ·94; 3 minutes, oxygen ·47.

J. Carter Bell.

March 12th, 1903.

SALFORD—*continued.*

March, 1903.

SEWAGE.—

Average daily flow - - - - - -	11,006,000 gallons	-	Total rainfall - - - 3·706 inches
Maximum daily flow, March 17th - -	17,570,000 „	-	Rainfall, March 18th - - - ·620 „
Minimum daily flow, March 8th - - -	7,675,000 „	-	Rainfall, March 9th and 20th ·002 „

Average analysis of sewage - - - - - - - 4 hours ; oxygen, 4·4

Number of samples analysed for the average - - - 62.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - - - - - - 13½ cwt. lime and 4½ cwt. copperas per million gallons

Amount of Sludge dealt with - - - - - - 8,500 tons.

Average analysis of Tank Liquor - - - - - - 4 hours, oxygen, 3·1 ; alkalinity of effluent, 3·0; suspended matter, 2·9.

Number of samples analysed for the average - - - 62. 219.

FILTERS.—

Amount treated on Filters during month - - - - 46,314,000 gallons.

Number of hours during which Filters were at work - 122.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - - - 195.

Average analysis of Final Effluent - - - - - 3 minutes, oxygen, ·22 ; 4 hours, oxygen, ·46 ; 3 minutes, oxygen, after 7 days' incubation, ·17 ; free ammonia, ·24 ; albuminoid ammonia, ·09 ; nitrogen as nitrates, ·87.

Number of samples analysed for the average - - 31.

Best analysis of Final Effluent, March 15th - - - 3 minutes, oxygen, ·1 ; 4 hours, oxygen, ·19

Worst analysis of Final Effluent, March 1st - - - 3 minutes, oxygen, ·3 ; 4 hours, oxygen, ·66.

REMARKS.—The total capacity of the Filters is 46,743 cubic yards.

J. Carter Bell.

March 31st, 1903.

SALFORD—*continued.*

April, 1903.

SEWAGE.—

Average daily flow - - - - - - -	9,610,500 gallons	- -	Rainfall - - - -
Maximum daily flow, April 3rd - - -	13,280,000 ,	- -	Rainfall - - - -
Minimum daily flow, April 10th - - - - -	6,265,000 ,	- -	Rainfall - - - -
Average analysis of Sewage - - - - -	4 hours, oxygen, 5·0.		
Number of samples analysed for the average - -	60.		

PRECIPITATED SEWAGE.—

Amount of Chemicals added - - -	13½ cwt. lime and 4½ cwt. copperas per million gallons.
Amount of Sludge dealt with - - -	8,900 tons.
Average analysis of Tank Liquor - - - -	4 hours, oxygen, 3·5 ; alkalinity, 2·5 ; suspended matter, 2·4.
Number of samples analysed for the average - -	4 hours, oxygen, 60 ; alkalinity, 230.

FILTERS —

Amount treated on Filters during month -	298,315,000 gallons.
Number of hours during which Filters were at work -	360.
Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - - -	205·6.
Average analysis of Final Effluent - - - -	4 hours, oxygen, ·69 ; 3 minutes, oxygen, ·34 ; 3 minutes oxygen (after 7 days incubation at 85° Fahr.), ·24 free Ammonia, ·74 ; albuminoid ammonia, ·11 ; nitrates ·33.
Number of samples analysed for the average - -	90.
Best analysis of Final Effluent, April 10th - - -	4 hours, oxygen, ·36 ; 3 minutes oxygen, ·2.
Worst analysis of final effluent, April 24th - - -	4 hours, oxygen, 1·12 ; 3 minutes, oxygen, ·56.

REMARKS.—The whole of the Salford Sewage is now being treated by the Filters.

J. Carter Bell.

The Cliff, Manchester,
May 6th, 1903.

SALFORD—*continued.*

SEWAGE.— May, 1903.

Average daily flow	11,126,000 gallons	Rainfall	
Maximum daily flow, May 3rd	15,000,000 „	Rainfall	·440 inches.
Minimum daily flow, May 15th	10,095,000 „	Rainfall	·045 „
Average analysis of Sewage	4 hours, oxygen, 4·3		
Number of samples analysed for the average	29		

PRECIPITATED SEWAGE.—

Amount of Chemicals added	13 cwts. lime and 4 cwts. copperas per million gallons.
Amount of Sludge dealt with	10,000 tons.
Average analysis of Tank Liquor	4 hours, oxygen, 3·3; free lime, 2·5; suspended matter 2·1.
Number of samples analysed for the average	225.

FILTERS.—

Amount treated on Filters during month	330,000,000 gallons.
Number of hours during which Filters were at work	696.
Rate of filtration (gallons per cube yard of filtering material per 24 hours)	253.
Average analysis of Final Effluent	3 minutes, oxygen, ·32 ; 4 hours, oxygen, ·97 ; free ammonia. ·5 ; albuminoid ammonia, 09 ; nitrates, ·2 ; 3 minutes oxygen after 7 days' incubation, ·26.
Number of samples analysed for the average	58
Best analysis of Final Effluent, May 4th	4 hours, oxygen, ·32 ; 3 minutes, oxygen, ·14 ; 3 minutes. oxygen, after incubation, ·12.
Worst analysis of Final Effluent, May 27th	4 hours, oxygen 1·24 ; 3 minutes, oxygen, ·64 ; 3 minutes. oxygen after 7 days' incubation, ·65.

J. Carter Bell.

The Cliff, Manchester,
June 25th, 1903.

SALFORD—*continued.*

June, 1903.

SEWAGE.—

Average daily flow - - - - -	9,320,800 gallons	-	Rainfall - - - - -
Maximum daily flow, June 27th - - -	12,440,000 „	-	Rainfall - - - - -
Minimum daily flow, June 21st - - -	7,445,000 „	-	Rainfall - - - - -

Average analysis of Sewage - - - - - - - 4 hours, oxygen ; 5·4 grains per gallon.

Number of samples analysed for the average - - 23.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - - - - - - 10¾ cwts. lime and 3 cwts. copperas per million gallons.

Amount of Sludge dealt with - - - - - - 9,255 tons.

Average analysis of Tank Liquor - - - - - 4 hours, oxygen, 3·9 ; free lime, 1·5 ; suspended matter, 2·8

Number of samples analysed for the average - - 183.

FILTERS.—

Amount treated on Filters during month - - - 154,760,000 gallons.

Number of hours during which Filters were at work - 192.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - - 110·4.

Average analysis of Final Effluent - - - - - 4 hours, oxygen, ·58 ; 3 minutes, oxygen, ·25 ; 3 minutes, oxygen, after incubation, ·23 ; free ammonia, ·33 ; albuminoid ammonia, ·09 ; nitrates, ·16.

Number of samples analysed for the average - - 54.

Best analysis of Final Effluent, June 15th - - - 4 hours, oxygen, ·35 ; 3 minutes, oxygen, ·18 ; 3 minutes, oxygen, after incubation, ·2 ; free ammonia, ·3 ; albuminoid ammonia, ·08 ; nitrates, ·12.

Worst analysis of Final Effluent, June 8th - - 4 hours, oxygen, ·88 ; 3 minutes. oxygen, ·3 ; 3 minutes, oxygen, after incubation, ·3 ; free ammonia, ·7 ; albuminoid ammonia, ·16 ; nitrates, ·45.

REMARKS.—The average month's analysis is very similar to previous month's.

J. Carter Bell.

July 11th, 1903.

SALFORD—*continued*

July, 1903.

SEWAGE.—

Average daily flow	10,360,000 gallons	Rainfall	
Maximum daily flow, July 22nd	15,710,000 „	Rainfall	·600
Minimum daily flow, July 20th	7,700,000 „	Rainfall	nil.
Average analysis of Sewage	4 hours, oxygen, 4·0 grains per gallon.		
Number of samples analysed for the average	31.		

PRECIPITATED SEWAGE.—

Amount of Chemicals added	12½ cwts. lime and 4½ cwts. copperas per million gallons.
Amount of Sludge dealt with	8,000 tons.
Average analysis of Tank Liquor	4 hours, oxygen, 2·5 grains per gallon; free lime, 2·5 grains per gallon; suspended matter, 3·9.
Number of samples analysed for the average	31, 223.

FILTERS.—

Amount treated on Filters during month	321,165,000 gallons.
Number of hours during which Filters were at work	372.
Rate of filtration (gallons per cube yard of filtering material per 24 hours)	221·2.
Average analysis of Final Effluent	3 minutes, oxygen, ·21; 4 hours, oxygen, ·48; free ammonia, ·4; albuminoid ammonia, ·1; nitrates, ·37; 3 minutes, oxygen, after 7 days' incubation at 85° Fahr., ·19.
Number of samples analysed for the average	31.
Best analysis of Final Effluent, July 13th	3 minutes, oxygen, ·12; 4 hours, oxygen, ·29; 3 minutes, oxygen, after incubation, ·10.
Worst analysis of Final Effluent, July 22nd	3 minutes, oxygen, ·27; 4 hours, oxygen, ·69; 3 minutes, oxygen, after incubation, ·2[illegible]

J. Carter Bell.

August 12th, 1903.

SALFORD—*continued.*

August, 1903.

SEWAGE.—

Average daily flow	12,215,000 gallons	-	Rainfall
Maximum daily flow, August 16th	17,365,000 „	-	Rainfall
Minimum daily flow, August 30th	7,115,000 „	-	Rainfall

Average analysis of Sewage - 4 hours, oxygen, 3·0 grains per gallon.

Number of samples analysed for the average - 31.

PRECIPITATED SEWAGE.—

Amount of Chemicals added	$4\frac{3}{4}$ cwt. copperas ; $12\frac{1}{2}$ cwt. lime.
Amount of Sludge dealt with	6,575 tons.
Average analysis of Tank Liquor	4 hours, oxygen, 2·5 ; free lime, 2·5 ; suspended matter, 2·4.
Number of samples analysed for the average	4 hours, oxygen, 31 ; free lime, 208 ; total 39

FILTERS.—

Amount treated on Filters during month	378,690,000 gallons.
Number of hours during which Filters were at work	372.
Rate of filtration (gallons per cube yard of filtering material per 24 hours)	261.
Average analysis of Final Effluent	4 hours, oxygen, ·48 ; 3 minutes, oxygen, ·23 ; 3 minutes, oxygen, after 7 days' incubation, ·14 ; free ammonia, ·25 ; albuminoid ammonia, ·08 ; nitrates, ·55.
Number of samples analysed for the average	31.
Best analysis of Final Effluent, August 4th	4 hours, oxygen, ·28 ; 3 minutes, oxygen, ·16 ; 3 minutes, oxygen, after 7 days' incubation, ·10.
Worst analysis of Final Effluent, August 12th	4 hours, oxygen, ·89 ; 3 minutes, oxygen, ·47 ; 3 minutes, oxygen, after 7 days' incubation, ·26 ; free ammonia ·3 ; albuminoid ammonia, ·09 ; nitrates, ·5.

J. Carter Bell.

September 27th, 1903.

SALFORD—*continued.*

September, 1903.

SEWAGE—

Average daily flow	12,488,000 gallons	Rainfall
Maximum daily flow, Sept. 9th	22,725,000 „	Rainfall
Minimum daily flow, Sept. 20th	7,505.000 „	Rainfall

Average analysis of Sewage - 4 hours, oxygen 3·5 grains per gallon; suspended matter, 42 grains per gallon.

Number of samples analysed for the average - 30.

PRECIPITATED SEWAGE—

Amount of Chemicals added - 14¼ cwts. lime and 5 cwts. copperas per million gallons.

Amount of Sludge dealt with - 7,890 tons.

Average analysis of Tank Liquor - 4 hours, oxygen, 2·3 grains per gallon; free lime, 2·0 grains per gallon; suspended matter, 2·0 grains per gallon.

Number of samples analysed for the average - 30. 200.

FILTERS—

Amount treated on Filters during month - 374,630,000 gallons.

Number of hours during which Filters were at work - 360.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - 267·1.

Average analysis of Final Effluent - 4 hours, oxygen, ·42; 3 minutes, oxygen, ·20; 3 minutes, oxygen, after 7 days' incubation; ·17; free ammonia, ·6; albuminoid ammonia ·1; nitrogen as nitrates, ·48.

Number of samples analysed for the average - 30.

Best analysis of Final Effluent, September 13th - 4 hours, oxygen, ·26; 3 minutes, oxygen, ·15; 3 minutes, oxygen, after 7 days' incubation, ·10; free ammonia, ·5; albuminoid ammonia, ·1; nitrogen as nitrates, ·41.

Worst analysis of Final Effluent, September 17th - 4 hours, oxygen, ·65; 3 minutes, oxygen, ·33; 3 minutes, oxygen, after 7 days' incubation, ·32; free ammonia, ·4; albuminoid ammonia, ·1; nitrogen as nitrates, ·49.

J. Carter Bell.

October 15th, 1903.

SALFORD—*continued.*

October, 1903.

SEWAGE—

Average daily flow - - - - 15,139,200 gallons - - - - Rainfall - - - - ——

Maximum daily flow, Oct. 15th - - 23,910,000 „ - - - - - Rainfall - - - - ——

Minimum daily flow, Oct. 4th - - 8,915,000 „ - - - - - Rainfall - - - - ——

Average analysis of sewage- - - - - 4 hours, oxygen, 2·7 grains per gallon ; suspended mater, 58·0 grains per gallon.

Number of samples analysed for the average - 31.

PRECIPITATED SEWAGE—

Amount of Chemicals added - - - - - 13 cwts. lime and 5 cwts. copperas per million gallons,

Amount of Sludge dealt with - - - - - - - - - - - - - - - - 8,462 tons.

Average analysis of Tank Liquor - 4 hours, oxygen, 2·2 grains per gallon ; free lime, 2·0 grains per gallons suspended matter 1·8 grains per gallon.

Number of samples analysed for the average - - 31. 212.

FILTERS—

Amount treated on Filters during month - - - - - - - - - - - 30,8522,500 gallons

Number of hours during which Filters were at work - - - - - - - - 276.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - 226·4.

Average analysis of Final Effluent - - - - 4 hours, oxygen, ·36 ; 3 minutes, oxygen, ·17 ; 3 minutes. oxygen, after 7 days' incubation, ·15 ; free ammonia, ·40 ; albuminoid ammonia, ·09 ; N. as nitrates (expressed as N.), ·72.

Number of samples analysed for the average- - - 31.

Best analysis of Final Effluent, October 17th - - 4 hours, oxygen, ·28 ; 3 minutes, oxygen, ·13 ; 3 minutes, oxygen, after 7 days at 85° Fahr., ·13 ; free ammonia, ·3 ; albuminoid ammonia, ·07 ; nitrates, ·98.

Worst analysis of Final Effluent, October 12th - - 4 hours, oxygen, ·62 ; 3 minutes, oxygen, ·31 ; 3 minutes, oxygen, after 7 days at 85° Fahr., ·21 ; free ammonia, 1·2 ; albuminoid ammonia, ·12 ; nitrates, ·65.

November 20th, 1903. *J. Carter Bell.*

SALFORD—*continued.*

November, 1903.

SEWAGE—

Average daily flow - - - - - -	11,234.000 gallons	-	Rainfall - - - -
Maximum daily flow, November 3rd - -	14,505,000 „	-	Rainfall - - -
Minimum daily flow, November 2nd - -	8,180,000 „	-	Rainfall - - - -
Average analysis of sewage - - - - - -	4 hours, oxygen, 3·7 grains per gallon; suspended matter, 42·0 grains per gallon.		
Number of samples analysed for the average - -	30.		

PRECIPITATED SEWAGE—

Amount of Chemicals added - - - - - -	7¼ cwts. lime and 3⅛ cwts. copperas per million gallons.
Amount of Sludge dealt with - - - - - -	7,260 tons.
Average analysis of Tank Liquor - - - - -	4 hours, oxygen, 2·4; free lime, 2·0; suspended matter, 1·6.
Number of samples analysed for the average - -	30. 213.

FILTERS—

Amount treated on Filters during month - - -	168,512,000 gallons.
Number of hours during which Filters were at work -	360.
Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - - -	120.
Average analysis of Final Effluent - - - - -	4 hours, oxygen, ·36; 3 minutes, oxygen, ·18; 3 minutes, oxygen, after 7 days at 90° Fahr., ·16; free ammonia, ·50; albuminoid ammonia, ·09; nitrates as N., ·78; suspended matter 1·0.
Number of samples analysed for the average - -	30.
Best analysis of Final Effluent, November 29th - -	4 hours, oxygen, ·21; 3 minutes, oxygen, ·11; 3 minutes, oxygen, after 7 days' incubation at 90° Fahr., ·12; free ammonia, ·30; albuminoid ammonia, ·08; nitrates as N., ·82.
Worst analysis of Final Effluent, November 9th - -	4 hours, oxygen, ·57; 3 minutes, oxygen, ·27; 3 minutes oxygen, after 7 days' incubation at 90° Fahr., ·18; free ammonia, ·50; albuminoid ammonia, ·14; nitrates as N., ·82.

J. Carter Bell.

December 21st, 1903.

SALFORD—*continued.*

December, 1903.

SEWAGE—

Average daily flow - - - - - - 9,914,230 gallons - Rainfall - - - - -

Maximum daily flow, December 1st - - 13,124,000 „ - Rainfall - - - - -

Minimum daily flow, December 28th - - 7,435,000 „ - Rainfall - - - - - nil.

Average analysis of Sewage - - - - - - 4 hours, oxygen, 5·2 grains per gallon ; suspended matter, 52·0 grains per gallon.

Number of samples analysed for the average - - 31

PRECIPITATED SEWAGE—

Amount of Chemicals added - - - - - 5½ cwts. lime and 2½ cwts. copperas per million gallons.

Amount of Sludge dealt with - - - - - 9,150 tons.

Average analysis of Tank Liquor - - - - - 4 hours, oxygen, 3·5 grains per gallon ; free lime, 1·5 grains per gallon ; suspended matter, 1·8.

Number of samples analysed for the average - - 31. 216.

FILTERS—

Amount treated on Filters during month - - - 153,679,500 gallons.

Number of hours during which Filters were at work - 186.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - - 106 gallons.

Average analysis of Final Effluent - - - - 4 hours, oxygen, ·52 ; 3 minutes, oxygen, ·27 ; 3 minutes, oxygen, after 7 days' incubation at 90° Fahr., ·18 ; free ammonia, ·73 ; albuminoid ammonia, ·09 ; nitrates as N., ·79 ; suspended matter, ·8.

Number of samples analysed for the average - - 31.

Best analysis of Final Effluent, December 2nd - - 4 hours, oxygen, ·32 ; 3 minutes, oxygen, ·19 ; 3 minutes, oxygen, after 7 days' incubation at 90° Fahr., ·12 ; free ammonia, ·25 ; albuminoid ammonia, ·07 ; nitrates as N., ·98.

Worst analysis of Final Effluent, December 26th - - 4 hours, oxygen, 1·05 ; 3 minutes, oxygen, ·62 ; 3 minutes, oxygen, after 7 days' incubation at 90° Fahr., ·47 ; free ammonia, 1·4 ; albuminoid ammonia, ·12 ; nitrates as N., ·49.

January 11th, 1904.

J Carter Bell.

SALFORD—*continued.*

January, 1904.

SEWAGE.—

Average daily flow - - - - -	9,271,774 gallons	- - - - -	Rainfall - - - ·845
Maximum daily flow, January 13th -	14,870,000 „	- - - - -	Rainfall - - - ·110.
Minimum daily flow, January 25th -	6,295,000 „	- - - - -	Rainfall - - - nil.

Average analysis of Sewage - - - - - - 4 hours, oxygen, 4·8; alkalinity, ·4; suspended matter, 35·0.

Number of samples analysed for the average - - 31. 124.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - - - - - - 5½ cwts. lime and 3½ cwts. copperas per million gallons.

Amount of Sludge dealt with - - - - - - 7,465 tons.

Average analysis of Tank Liquor - - - - 4 hours, oxygen, 3·6; free lime, 1·5; suspended matter, 2·1.

Number of samples analysed for the average - - - 31. 208. 31.

FILTERS.—

Amount treated on Filters during month - - - - - - - 71,855,000 gallons.

Number of hours during which Filters were at work - - - - - - - - 186.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - 49·6.

Average analysis of Final Effluent - - - - 4 hours, oxygen, ·56; 3 minutes, oxygen, ·28; 3 minutes, oxygen, after 7 days' incubation, ·21; free ammonia, ·70; albuminoid ammonia, ·11; nitrates as N., 71; suspended matter, 1·1.

Number of samples analysed for the average - - 31.

Best analysis of Final Effluent, January 30th - - hours, oxygen, ·30; 3 minutes, oxygen, ·19; 3 minutes, oxygen, after 7 days' incubation, ·19: free ammonia, ·20; albuminoid ammonia, ·09; nitrates as N., ·82.

Worst analysis of Final Effluent, January 10th - - 4 hours, oxygen, 1·10; 3 minutes, oxygen, ·60; 3 minutes, oxygen, after 7 days' incubation, ·30; free ammonia, 1·0; albuminoid ammonia, ·14; nitrates as N., ·49.

REMARKS.—The Effluents this month have been very good.

February 25th, 1904. *J. Carter Bell.*

SALFORD—*continued.*

February, 1904.

SEWAGE.—

Average daily flow - - - - - -	8,840,300 gallons	Rainfall - - - ——
Maximum daily flow, February 26th - -	11,066,000 „	Rainfall - - - - - ——
Minimum daily flow, February 16th - -	6,048,000 „	Rainfall - - - - ——
Average analysis of Sewage - - - - - - -	4 hours, oxygen, 4·6 grains per gallon ; alkalinity (as CaO), 0·25 grains per gallon ; suspended matter, 42·0.	
Number of samples analysed for the average - - - -	29.	116.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - - - - -	5½ cwts. lime and 2½ cwts. copperas per million gallons.		
Amount of Sludge dealt with - - - - -	5,830 tons.		
Average analysis of Tank Liquor - - - -	4 hours, oxygen, 3·0 grains per gallon ; free lime, 1·7 grains per gallon ; suspended matter, 1·8.		
Number of samples analysed for the average -	29.	200.	29.

FILTERS.—

Amount treated on Filters during month - - -	64,092,750 gallons.
Number of hours during which filters were at work - -	183.
Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - - -	47·3.
Average analysis of Final Effluent - - - - -	4 hours, oxygen, ·35 ; 3 minutes, oxygen, ·18 ; 3 minutes oxygen, after 7 days' incubation, ·16 ; free ammonia. ·40 ; albuminoid ammonia, ·08; nitrates as N., 1·04 ; suspended matter, ·6.
Number of samples analysed for the average - - -	29.
Best analysis of Final Effluent, February 27th - -	4 hours, oxygen, ·22 ; 3 minutes, oxygen, ·13 ; 3 minutes, oxygen, after 7 days' incubation, ·08 ; free ammonia, ·5 ; albuminoid ammonia, ·08 ; nitrates as N., ·98.
Worst analysis of Final Effluent, February 16th - - -	4 hours, oxygen, ·47 ; 3 minutes, oxygen, ·23 ; 3 minutes, oxygen, after 7 days' incubation, ·18 ; free ammonia, ·3 ; albuminoid ammonia, ·08 ; nitrates as N., ·90.

J. Carter Bell.

March 20th, 1904.

SALFORD—*continued.*

March, 1904.

SEWAGE.—

Average daily flow	9,115,660 gallons	Total rainfall	1·942 inches.
Maximum daily flow, March 19th	10,739,670 „	Rainfall	·065 „
Minimum daily flow, March 29th	6,280,700 „	Rainfall	·235 „

Average analysis of sewage - 4 hours, oxygen, 5·9 grains per gallon; suspended matter, 24 grains per gallon.

Number of samples analysed for the average - 31.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - $4\frac{3}{4}$ cwts. lime and $2\frac{1}{2}$ cwts. copperas per million gallons.

Amount of Sludge dealt with - 5,800 tons.

Average analysis of Tank Liquor - 4 hours, oxygen, 3·6 grains per gallon; free lime, 2·0 grains per gallon; suspended matter, 1·8.

Number of samples analysed for the average - 31. 208. 31.

FILTERS.—

Amount treated on Filters during month - 133,920,000 gallons.

Number of hours during which Filters were at work - 93.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - $92\frac{1}{2}$ gallons.

Average analysis of Final Effluent - 3 minutes, oxygen, ·21 grains per gallon; 4 hours, oxygen, ·43; free ammonia, ·8; albuminoid ammonia, ·10; nitrates as N., 1·10; 3 minutes, oxygen, after 7 days, incubation, ·16; suspended matter, ·6.

Number of samples analysed for the average - 31.

Best analysis of Final Effluent, March 5th - 4 hours, oxygen, ·29 grains per gallon; 3 minutes, oxygen, ·14; 3 minutes, oxygen, after 7 days' incubation, ·10; free ammonia, ·3; albuminoid ammonia, ·06; nitrates as N., 1·31.

Worst analysis of Final Effluent, March 7th - 4 hours, oxygen, ·56 grains per gallon; 3 minutes, oxygen, ·29; 3 minutes, oxygen, after 7 days' incubation, ·20; free ammonia, 1·1; albuminoid ammonia, ·08; nitrates as N., 1·07.

J. Carter Bell.

April 10th, 1904.

SALFORD—*continued.*

April, 1904.

SEWAGE.

Average daily flow	8,352,160 gallons	Rainfall	·0528 inches.
Maximum daily flow, April 8th	10,960,560 „	Rainfall	·060 „
Minimum daily flow, April 26th	5,254,700 „	Rainfall	·052 „

Average analysis of sewage - 4 hours oxygen, 5·1 grains per gallon ; suspended matter, 36 grains per gallon.

Number of samples analysed for the average - 30.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - 5 cwts. lime and 2½ cwts. copperas per million gallons.

Amount of Sludge dealt with - 4,500 tons.

Average analysis of Tank Liquor - 4 hours, oxygen, 3·4 grains per gallon ; free lime, 2·2 grains per gallon ; suspended matter, 1·7 grains per gallon.

Number of samples analysed for the average - 30. 204.

FILTERS.—

Amount treated on Filters during month - 125,282,400 gallons.

Number of hours during which Filters were at work - 90.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - 89·3.

Average analysis of Final Effluent - 4 hours, oxygen, ·43 ; 3 minutes, oxygen, 21 ; 3 minutes, oxygen, after 7 days' incubation, ·15 ; free ammonia, ·41 ; albuminoid ammonia, ·09 ; nitrates as N., 1·18 ; suspended matter, ·7.

Number of samples analysed for the average - 30.

Best analysis of Final Effluent, April 11th - 4 hours, oxygen, ·32 ; 3 minutes, oxygen, ·17 ; 3 minutes, oxygen, after 7 days' incubation, ·15 ; free and saline ammonia, ·3 ; albuminoid ammonia, ·08 ; nitrates as N., ·82.

Worst analysis of Final Effluent, April 18th - 4 hours, oxygen, ·61 ; 3 minutes, oxygen, ·24 ; 3 minutes, oxygen, after 7 days' incubation, ·15 ; free and saline ammonia, ·5 ; albuminoid ammonia, ·09 ; nitrates as N., 1·31.

J. Carter Bell.

May 8th, 1904.

SALFORD—*continued.*

May, 1904.

SEWAGE.—

Average daily flow	7,951,104 gallons		Rainfall 0·77
Maximum daily flow	9,890,400 „	May 15th	Rainfall Nil.
Minimum daily flow	5,260,944 „	May 7th	Rainfall 0·78.

Average analysis of sewage - 4 hours, oxygen, 5·3 grains per gallon; suspended matter, 38·0 grains per gallon.

Number of sample analysed for the average - 31.

PRECIPITATED SEWAGE.—

Amount of Chemicals added	5¼ cwts. lime, 2 cwts. copperas per million gallons.
Amount of Sludge dealt with	4,960 tons.
Average analysis of Tank Liquor	4 hours, oxygen, 3·7 grains per gallon; free lime, 2·7 grains per gallon; suspended matter, 2·1 grains per gallon.
Number of samples analysed for the average	31. 500.

FILTERS.—

Amount treated on Filters during month	73,897,672 gallons.
Number of hours during which Filters were at work	93.
Rate of filtration (gallons per cube yard of filtering material per 24 hours)	51.
Average analysis of Final Effluent	4 hours, oxygen, ·37 grains per gallon; 3 minutes, oxygen, ·17 grains per gallon; 3 minutes, oxygen, after 7 days' incubation, ·16 grains per gallon; free ammonia, ·25 grains per gallon; albuminoid ammonia, ·086 grains per gallon; nitrates, 1·87 grains per gallon; suspended matter, ·6.
Number of samples analysed for the average	31.
Best analysis of Final Effluent, May 29th	4 hours, oxygen, ·25; 3 minutes, oxygen, ·12; 3 minutes, oxygen, after 7 days' incubation at 80° Fahr., ·12; free ammonia, ·25; albuminoid ammonia, ·08; nitrates, 2·30.
Worst analysis of Final Effluent, May 7th	4 hours, oxygen, ·52; 3 minutes, oxygen, ·23; 3 minutes, oxygen, after 7 days' incubation at 80° Fahr., ·18; free ammonia, ·27; albuminoid ammonia, ·09; nitrates, ·33.

May 31st, 1904.

J. Carter Bell.

SALFORD—*continued.*

June, 1904.

SEWAGE.— Total Rainfall ·93.

Average daily flow - - - - - -	8,253,000 gallons	- Rainfall -	·031 inches.
Maximum daily flow, June 30th - - -	11,662,000 ,,	- Rainfall - - - - -	nil.
Minimum daily flow, June 21st - - -	4,814,000 ,,	- Rainfall - - - - -	nil.

Average analysis of sewage - - - - - - 4 hours, oxygen, 5·1 grains per gallon; suspended matter, 17.0 grains per gallon.

Number of samples analysed for the average - - 30.

PRECIPITATED SEWAGE.—

Amount of Chemicals added - - - - 6 cwts. lime and 3 cwts. copperas per million gallons.

Amount of Sludge dealt with - - - - - 6,980 tons.

Average analysis of Tank Liquor - - - - - 4 hours, oxygen, 3·5 ; free lime, 1·9 ; suspended matter, ·6.

Number of samples analysed for the average - - 30. 208.

FILTERS.—

Amount treated on Filters during month - - - 123,795,000 gallons.

Number of hours during which Filters were at work - 93.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) - - - - - 88.3.

Average analysis of Final Effluent - - - - 4 hours, oxygen, ·44 ; 3 minutes, oxygen, ·19 ; 3 minutes, oxygen, after 7 days' incubation, ·16 ; free ammonia, ·26 ; albumen, ·09 ; nitrates as N, 1·73 ; suspended matter, ·6.

Number of samples analysed for the average - - 30.

Best analysis of Final Effluent, June 3rd - - 4 hours, oxygen absorption, ·35 ; 3 minutes, oxygen absorption, ·19 ; 3 minutes, oxygen absorption, after 7 days' incubation, ·15 ; free ammonia, ·15 ; albumen, ·07 ; nitrates as N, 2·95.

Worst analysis of Final Effluent, June 30th - 4 hours, oxygen absorption, ·70 ; 3 minutes, oxygen absorption, ·31 ; 3 minutes, oxygen absorption, after 7 days, incubation, ·20 ; free ammonia, 1·0 ; albumen, ·14 ; nitrates as N, ·66.

July 5th, 1904. *J. Carter Bell.*

SALFORD—*continued.*

SEWAGE.— July, 1904.

Average daily flow	7,723,000 gallons	Total Rainfall	1·120
Maximum daily flow	9,294,500 „ July 3rd	Total Rainfall	·011
Minimum daily flow	3,429,500 „ July 19th	Total Rainfall	nil.

Average analysis of Sewage — 4 hours, oxygen, 5·5 grains per gallon; suspended matter, 23 grains per gallon.

Number of samples analysed for the average — 31.

PRECIPITATED SEWAGE.—

Amount of Chemicals added — 6 cwts. lime and 3 cwts. copperas per million gallons.

Amount of Sludge dealt with — 7,600 tons.

Average analysis of Tank Liquor — 4 hours, oxygen, 3·8 ; free lime, 1·1 ; suspended matter, 2·9.

Number of samples analysed for the average — 31. 208.

FILTERS.—

Amount treated on Filters during the month — 119,709,000 gallons.

Number of hours during which Filters were at work — 93.

Rate of filtration (gallons per cube yard of filtering material per 24 hours) — 82½ gallons.

Average analysis of Final Effluent — 4 hours, oxygen, ·42 ; 3 minutes, oxygen, ·23 ; 3 minutes, oxygen, after 7 days' incubation, ·20 ; free ammonia, ·60 ; albuminoid ammonia, ·098 ; nitrates as N, 1·76 ; suspended matter, ·7.

Number of samples analysed for the average — 31.

Best analysis of Final Effluent, July 31st — 4 hours, oxygen, ·28 ; 3 minutes, oxygen, ·16 ; 3 minutes, oxygen, after 7 days' incubation, 15 ; free ammonia, 35 ; albuminoid ammonia, ·08 ; nitrates as N, 1·61.

Worst analysis of Final Effluent, July 12th — 4 hours, oxygen, ·91 ; 3 minutes, oxygen, ·37 ; 3 minutes, oxygen, after 7 days' incubation, ·22 ; free ammonia, 1·5 ; albuminoid ammonia, ·16 ; nitrates as N, ·92.

The suspended matter in the filtered effluent is estimated once a week on a mixture of the 7 daily samples.

August 15th, 1904.

J. Carter Bell.

SALFORD—*continued.*

August, 1904.

SEWAGE.—

Average daily flow - - - - 7,754,763 gallons - - - - - - Rainfall - - -
Maximum daily flow - - - - 11,751,648 „ (August 26th) - - Rainfall - - -
Minimum daily flow - - - - 4,924,400 „ (August 14th) - - Rainfall - - -

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	1·7	7·3	4·5 grains per gallon.
Suspended matter - - - - - - - - -	18·3	62·0	28 ·0

Number of samples analysed for the average = 31.

PRECIPITATION TANKS.—

Amount of Chemicals used - - - - - - 6 cwts. lime, 3 cwts. copperas per million gallons.
Amount of Sludge dealt with during the month - - 7,550 tons.

Average Analysis of Tank Liquor.

	Best.	Worst.	Average.
Ammoniacal Nitrogen - - - - - - - -	—	—	—
Albuminoid Nitrogen - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	1·6	5·1	3·5
Alkalinity as CaO - - - - - - - - -	·4	4·8	1·2
Suspended matter - - - - - - - - -	1·3	4·4	2·8

Number of samples analysed for the average = Oxygen absorbed, 31 ; alkalinity, 208 ; suspended matter, 31.

FILTERS.

Quantity of effluent filtered during month - - - - - - - - 120,198,800 gallons.
Estimate of amount of tank liquor treated per cube yard per 24 hours - 82·9 gallons.

Average Analysis of Filter Effluent.

	Best, Aug. 20th.	Worst. Aug. 8th.	Average.
Ammoniacal Nitrogen as NH_3 - - - - - - -	·10	·40	·24
Albuminoid Nitrogen as NH_3 - - - - - - -	·06	·10	·07
Nitric Nitrogen as N - - - - - - -	1·26	2·30	1·74
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	·26	·60	·41
Oxygen absorbed from $KMnO_4$ in 3 minutes - - -	·10	·25	·18
Oxygen absorbed after 7 days' incubation - - -	·10	·28	·17
Suspended matter - - - - - - - - -	—	—	·70

Number of samples analysed for the average = 31.

October 28th, 1904. *J. Carter Bell.*

SALFORD—*continued.*

September, 1904.

SEWAGE.—

Average daily flow - - - - - 9,205,280 gallons - - - Rainfall - -

Maximum daily flow - - - - - 10,539,360 „ - - - Rainfall - -

Minimum daily flow - - - - - 5,805,100 „ - - - Rainfall - -

Average Analysis of Sewage.

	Best. September 4th.	Worst. September 10th.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·1	22·1	6·6
Suspended matter	21·0	48·0	29·0

Number of samples analysed for the average=30.

PRECIPITATION TANKS.—

Quantity of Chemicals used - - - - - 6 cwts. lime and 3 cwts. copperas per million gallons

Amount of Sludge dealt with during the month - 6,730 tons.

Average Analysis of Tank Liquor.

	Best, September 5th.	Worst, September 21st.	Average.
Ammoniacal Nitrogen	—	—	—
Albuminoid Nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	2·0	8·1	4·2
Free Lime	3·7	1·1	1·6
Suspended matter	1·7	2·5	1·9

Number of samples analysed for the average - - Oxygen absorbed, 30; free lime, 212; suspended matter, 30.

FILTERS.—

Quantity of Effluent filtered during month - - - - - 138,079,200 gallons.

Estimate of amount of Tank Liquor treated per cube yard per 24 hours 98·2 gallons.

A.—Primary Beds. B.—Storm-filters.

Average Analysis of Filter Effluent.

	Best, September 27th.	Worst, September 2nd.	Average.
Ammoniacal Nitrogen as NH_3	·35	·32	·35
Albuminoid Nitrogen as NH_3	·08	·08	·07
Nitric Nitrogen as N.	1·83	2·46	1·81
Oxygen absorbed from $KMnO_4$ in 4 hours	·28	·61	·41
Oxygen absorbed from $KMnO_4$ in 3 minutes	·14	·30	·19
Oxygen absorbed after 7 days' incubation	·12	·35	·16
Suspended matter	—	—	·52

Number of samples analysed for the average=30.

October 28th, 1904. *J. Carter Bell.*

SALFORD—*continued.*

October, 1904.

SEWAGE—

Average daily flow - - - 9,655,900 gallons - - - - Total rainfall - - - 1·491
Maximum daily flow - - - 11,013,600 „ October 19th - Rainfall - - - - Nil.
Minimum daily flow - - - 7,536,700 „ „ 4th - - Rainfall - - - - Nil.

Average Analysis of Sewage.

	Best. Oct. 30th.	Worst. Oct. 8th.	Average.
Suspended matter - - - - - - - -	28	21	53
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	3·3	11·5	6·0

Number of samples analysed for the average = Suspended matter, 31 ; Oxygen absorbed, 31.

PRECIPITATION TANKS—

Average daily flow through tanks - - - -
Amount of sludge dealt with during the month - 5,760 tons.

Average Analysis of Tank Liquor.

	Best. Oct. 18th.	Worst. Oct. 21st.	Average.
Alkalinity as CaO. - - - - - - - - -	1·9	2·1	2·5
Suspended matter - - - - - - - - -	1·1	1·3	2·0
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	1·6	6·9	4·0

Number of samples analysed for the average = Alkalinity (free lime), 270 ; Suspended matter, 31 ; Oxygen absorbed, 31.

FILTERS—

Total number of times primary beds were filled during the month -
Amount of chemicals used - - - - - - - - - - 6 cwts. lime, 3 cwts. copperas, per million gallons.
Quantity of tank effluent filtered during month - - - - 99,777,000 gallons.
Estimate of amount of tank liquor treated per cube yard per 24 hours - - - - - - - - - - - - 68·9 gallons.

A.—Primary Beds. B.—Storm-filters.

Average Analysis of Filter Effluent.

	Best. Oct. 3rd.	Worst. Oct. 13th.	Average.
Ammoniacal nitrogen as NH_3 - - - - - -	·04	·50	·33
Albuminoid nitrogen as NH_3 - - - - - -	·06	·11	·09
Nitric nitrogen as N - - - - - - - - -	2·38	·92	1·59
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	·27	61	·41
Oxygen absorbed from $KMnO_4$ in 3 minutes - - -	·10	·22	·18
Oxygen absorbed after 7 days' incubation - - - -	·09	·19	·15
Suspended matter - - - - - - - - -	—	—	·4

Number of samples analysed for the average = 31.

November, 1904. *J. Carter Bell.*

SALFORD—*continued.*

November, 1904.

SEWAGE—

Average daily flow	8,447,000 gallons		Total Rainfall		2·057
Maximum daily flow	12,664,000 „	November 30th	Rainfall		·028
Minimum daily flow	6,510,200 „	November 22nd	Rainfall		nil.

Average Analysis of Sewage.

	Best. 27th.	Worst. 30th.	Average.
Suspended Matter	19·0	22	42
Alkalinity as CaO	Nil	·6	·3
Oxygen absorbed from $KMnO_4$ in 4 hours	3·6	12·4	6·9

Number of samples analysed for the average = Oxygen absorbed, 30 ; Suspended Matter, 30 ; Alkalinity, 164.

PRECIPITATION TANKS—

Amount of Chemicals added - - - - 6 cwts. lime and 3 cwts. copperas per million gallons.

Amount of Sludge dealt with during the month 6,250 tons.

Average Analysis of Tank Liqour.

	Best. 1st.	Worst. 25th.	Average.
Suspended Matter	1·0	1·8	2·1
Free Lime as CaO	2·6	3.1	2·7
Oxygen absorbed from $KMnO_4$ in 4 hours	2·7	6·0	4·3

Number of samples analysed for the average = Suspended Matter, 30 ; Oxygen absorbed, 30 ; Free Lime, 268.

FILTERS—

Quantity of tank effluent filtered during the month - - - 84,600,000 gallons.

Estimate of amount of tank liquor treated per cube yard per 24 hours - - - - - - - - - - - 60·4 gallons.

A.—Primary Beds. B.—Storm-filters.

Average Analysis of Filter Effluent.

	Best. 6th.	Worst. 27th.	Average.
Ammoniacal Nitrogen	·24	1·20	·43
Albuminoid Nitrogen	·06	·12	·08
Nitric nitrogen.	2·75	·49	1·78
Oxygen absorbed from $KMnO_4$ in 4 hours	·27	·65	·38
Oxygen absorbed from $KMnO_4$ in 3 mins.	·14	·42	·19
Oxygen absorbed in 3 mins. after 7 days' incubation	·09	·20	·17
Suspended Matter	—	—	·18

Number of samples analysed for the average = 30.

December 10th, 1904.

J. Carter Bell.

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SALFORD—*continued*

December, 1904.

SEWAGE—

Average daily flow	11,478,000 gallons		Total rainfall	2·089 inches.
Maximum daily flow	13,654,000 „	Dec. 29th	Rainfall	·036 „
Minimum daily flow	6,976,000 „	Dec. 27th	Rainfall	nil. „

Analysis of Sewage.

	Best. December 5th.	Worst. December 8th.	Average.
Suspended matter	95·0	31·0	45·0
Oxygen absorbed from $KMnO_4$ in 4 hours.	3·3	11·9	5·3

Number of samples analysed for the average = Suspended matter, 31 ; Oxygen obsorbed, 31.

PRECIPITATION TANKS—

Amount of Chemicals added - 9 cwts. lime and 4 cwts. copperas per million gallons.

Amount of Sludge dealt with during month - 9,420 tons.

Average Analysis of Tank Liquor.

	Best. December 19th.	Worst. December 1st.	Average.
Suspended Matter	2·7	1·0	2·1
Oxygen absorbed from $KMnO_4$ in 4 hours	2·7	5·1	3·8
Alkalinity (as free CaO)	3·0	1·4	2·5

FILTERS.—

Quantity of Tank Effluent filtered during month - 118,609,000 gallons.

Quantity of Tank Effluent treated on filters per cube yard per 24 hours - 81·8 gallons.

Average Analysis of Filted Effluent.

	Best. December 20th.	Worst. December 5th.	Average.
Ammoniacal Nitrogen as NH_3	·30	·28	·20
Albuninoid Nitrogen as NH_3	·08	·07	·071
Nitric Nitrogen as N.	1·15	1·15	1·57
Oxygen absorbedfrom $KMnO_4$ in 4 hours	·19	·47	·28
Oxygen absorbed from $KMnO_4$ in 3 minutes	·08	·25	·13
Oxygen absorbed from $KMnO_4$ in 3 minutes after 7 days' incubation	·08	·19	·12
Suspended Matter	—	—	·22

Number of samples analysed for the average = 31.
All results are expressed in grains per gallon.

Mr. C. F. WIKE, M.INST.C.E., City Surveyor of Sheffield, called in; and Examined.

Mr. C. F. Wike, M. Inst. C.E.
15 May 1905.

23480. (*Chairman.*) You are Mr. Wike, member of the Institute of Civil Engineers and City Surveyor of Sheffield?—Yes.

23481. You have had general charge of the Sheffield Corporation Sewage Disposal Works?—Yes.

23482. What is the general character of the sewage treatment at Sheffield at present?—Principally precipitation by lime, but partially tank treatment followed by contact beds.

23483. What is the population draining to the Sheffield works?—It is estimated at 400,000. The total estimated population of the city is 433,000.

23484. What is the system of drainage? Is the storm water either wholly or partially drained into a separate system?—Sheffield is an old city, and it is only practicable to deal with a very small proportion of the storm water by separate sewers.

23485. Is there any infiltration of subsoil water into the sewers?—Yes, in the case of some of the older sewers, but these are gradually being replaced.

23486. What is the water supply per head, and from what source does it come?—Excluding supplies by the Sheffield Corporation to other authorities, the daily supply per head is 21·23 gallons, made up as follows:—

	Gallons.
Meter supplies (part trade, part domestic)	8·93
Domestic supplies, fire brigade, and waste (not by meter)	12·30
	21·23

The source of supply is a series of reservoirs to the west and north of the city, to be supplemented by a share of the Derwent Valley supply.

23487. Is it hard or soft water?—The water is soft.

23488. What is the drainage area of the part of the town which is sewered?—Of a total area of 23,654 acres it may be taken that about 9,000 acres are sewered. There is a large proportion of agricultural land and moorland in Sheffield.

23489. What proportion of the population use pail closets or middens, and what proportion use water closets?—The total number of inhabited houses in Sheffield is stated to me by the Medical Officer of Health as 93,000. The number of houses served by water closets is 39,000, and the remaining 54,000 houses are served by privies or pail closets. The estimated number of the latter is 174.

23490. Has the flow of sewage to the works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather in winter and in summer?—Yes, careful gaugings have been taken. The following are particulars:—

Month.	No. of dry days.	Average No. of gallons delivered at Works day of 24 hours.
1. WINTER PERIODS.		
1904.		
September	15	14,749,000.
December	11	14,144,000.
1905.		
January	12	14,348,000.
2. SUMMER PERIODS.		
1904.		
June	13	14,428,000.
July	20	14,340,000.

These figures account for more than purely domestic sewage and trade wastes. A large amount of fresh water entering the sewers ought to be turned into the rivers or streams. This has been gauged to the extent of 3,500,000 gallons per day.

23491. What is the maximum dry weather rate of flow, and at what hour does this occur?—At the rate of 19,400,000 gallons in 24 hours, occurring between noon and 4 p.m.

23492. What is the minimum dry weather rate of flow?—At the rate of 8,600,000 gallons in 24 hours, occurring between 1 a.m. and 5 a.m.

23493. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—The maximum treated flow at the works in wet weather is approximately 22,000,000 gallons in 24 hours. On one occasion a flow at the rate of 24,850,000 gallons in 24 hours was dealt with for a period of three hours.

23494. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation. Could you for comparative purposes give the maximum and minimum rates of flow in dry weather in the sewers on which the various overflows are situated?—There are about 80 storm overflows on the Sheffield sewers. It would be impossible without lengthy and expensive gaugings to give particulars as to the rates of flow at which they come into operation or the maximum and minimum rates of dry weather flow in the sewers on which such overflows are situated.

23495. What is the largest number of gallons which have passed the last storm overflow and come to your works in 24 hours?—Approximately 22,000,000 gallons.

23496. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—Taking the sewered area as 9,000 acres, and the average rainfall for five years at 31·596 in. per year, the volume would be 6,432,927,906 gallons.

23497. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year, and the volume which passes over your overflows?—As regards the former, the figures for the last six years are:—

Amount treated, year ending—

	Gallons.
March 25th, 1899	6,884,886,000
March 25th, 1900	6,952,480,000
March 25th, 1901	6,360,328,000
March 25th, 1902	6,098,370,000
March 25th, 1903	6,424,473,000
March 25th, 1904	6,498,534,000

It is impossible for me to say what volume passes over the overflows.

23498. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—No doubt this will vary with the seasons and with the state of the weather, but there are no means of gauging the amount of liquid. The defective sewers are gradually being replaced.

23499. How many gallons of trade effluents enter the sewers daily, and what is the nature of these effluents? Can you give analytical figures?—The quantity of trade effluent is estimated at an average of 2,000,000 gallons per day, exclusive of the fresh water I have referred to. The following is a schedule giving the nature of the effluents so far as it has been possible to ascertain this:—

1. Brewery waste (including barrel washings, vat washings, waste yeast, hops, and cooling water).
2. Iron pickle.
3. Tannery waste.
4. Tripe dressers' waste and fellmongers' waste.
5. Skin dressers' waste.
6. Ammonium sulphate waste and tarry matter.
7. Grain washings.
8. Bone drainings.
9. File-scouring and grinding waste.
10. Acetic acid pickle
11. Stone-cutting waste.
12. Bottle washings from mineral waters.
13. Washings from tobacco fermentation.
14. Coke slacking water.
15. Coal washings.

Mr. C. F. Wike, M. Inst. C.E.

15 May 1905.

16. Cooling water from rolling mills.
17. Ochre water.
18. Boiler blow-off water.
19. Oil.
20. Laundry waste.

23500. Has your authority framed any rules for the reception of trade effluents into the sewers?—At present there are no printed regulations governing the reception of trade effluents, but the question of framing such regulations is under consideration.

23501. Is it found that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume, or otherwise?—The trade effluents do interfere with the process of purification both by their quality and the fluctuations in their volume. The chemist is having continual experience of these effects.

23502. Is the Sheffield sewage a "strong" sewage, and, if so, what characterises its strength?—I consider the Sheffield sewage should be described as of medium strength. It can scarcely be described as a strong sewage on account of the dilution to which, as I have mentioned, it is subjected even under normal conditions.

23503. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—Its strength varies both on different days of the week and from hour to hour. On some days the trade wastes are very much reduced. The effects are traceable in the final effluents, but do not prevent satisfactory treatment. Analyses illustrating this point are handed in. (*See* Mr. Haworth's evidence.)

23504. Have you any information as to the bacteriological condition of the sewage?—No such information has been obtained.

23505. Do you find that the amounts of suspended solids are increased or diminished in times of storm, and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—The first effect of storm water is to largely increase the amount of suspended solids, but if the rainfall is prolonged the proportion afterwards diminishes. This effect I consider to be due to the fact that first of all the strong sewage is flushed out of the sewers together with any sediment which may have collected, and also to the fact that the rain quickly brings down the washings from the roads. Analyses illustrating this will be given. (*See* Mr. Haworth's evidence.)

23506. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—I can best answer that question by saying that the total mileage of sewers in Sheffield on March 25th, 1904, was about 286 miles, and of this total about 135 miles have been laid or relaid since 1888. When the main drainage scheme was carried out (1884-1886) about 16 miles of new sewers were laid, which are an addition to the 135 miles first mentioned, but are included in the total of 286 miles. I mention these figures to show that a large proportion of the Sheffield sewers are comparatively new, and therefore in good condition, and have gone somewhat into detail as evidence touching some of the same points has been given before another Commission, based, I feel sure, upon a misconception of the facts. Some of the remaining old sewers are somewhat roughly constructed of stone with open joints, and this, of course, has a tendency to accumulate solids, but such sewers are gradually being replaced.

23507. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely-increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—That, in my opinion, is a most important matter. In the case of Sheffield and other towns similarly circumstanced I think the requirements of the Local Government Board, as stated by you, might be modified, and the number of dilutions regulated by the strength of the sewage. The Sheffield sewage, as previously explained, is not a very strong one, and therefore a smaller number of dilutions might be accepted than in the case of a town where normally there is nothing but undiluted sewage to be treated. The proper way to regulate the number of dilutions appears to be by regular and careful observations both of the quantity and character of the sewage. It is a fact, as you state, that the storm sewage which first comes to the works contains a largely increased amount of suspended solids, and unless efficient means are taken to intercept these, the ordinary dry weather plant is undoubtedly exposed to damage by rapid choking. This is one of the great difficulties connected with purification by contact beds, and one which has received very careful consideration from me in preparing a scheme for dealing with the sewage of Sheffield. The difficulty is enhanced by the fact that many of our roads are of macadam. Where paving is more general there would, of course, be a smaller proportion of grit and other insoluble matter to deal with, and therefore less danger of choking the beds. Instead of providing separate storm beds, I think a better plan would be to lay down as many contact beds as practicable, and distribute the whole of the sewage and storm water which an authority is required to deal with in its works over the full number of beds—this, of course, after screening and settlement. It is scarcely practicable to absolutely divide the storm sewage into quantities representing the first three dilutions and three further dilutions, for the reason that if storm beds are not kept fed they will be useless from a bacteriological point of view when storm water is passed over them. To make them efficient they must be kept fed, and therefore a general distribution of the storm sewage would be more effective than the treatment of three dilutions by the ordinary means and three further dilutions on separate storm beds. If this suggestion were followed probably a better effluent would be obtained than by the other method. In the Sheffield scheme, in order to intercept the grit, etc., provision is made for passing the whole of the six dilutions through the continuous settlement tanks, which will have a capacity equal to about one and a quarter day's dry weather flow. Speaking from a practical point of view, I think, when fully diluted, the storm sewage might be sufficiently purified by settlement in these tanks without chemical precipitation or subsequent treatment on bacteria beds. As it is, the effect will probably be that when the river is swollen with storm water we shall be turning into it an effluent a good deal better than the river water itself, and the expense of getting such a good effluent will be wasted.

23508. What shape and size are your storm overflows?—The storm overflows are of many sizes and shapes. Perhaps it will be of more assistance to the Commissioners if I hand in drawings of typical overflows which I have had prepared for that purpose.

23509. Would it be possible to have a standard form of overflow, and how would you fix the point at which overflows should be allowed to come into operation?—I do not consider it practicable to have a standard form of overflow, as so much depends upon the position, size of sewers to be dealt with, contiguity of river or stream, and other points. The point at which the overflow should be allowed to come into operation must be governed partly by the position and importance of the sewers it serves. For instance, in Sheffield we have

a number of sewers laid in parallel streets with steep gradients, and emptying into a larger sewer with a flatter gradient running along a valley parallel with and close to the river. The sewers in these steep streets have no sewage standing in them, and consequently the overflows serving them might be allowed to come into operation without detriment to the river immediately there is a heavy rainfall. On the main sewer running along the valley the overflows should not be allowed to operate until the sewage is diluted several times, because that sewer, being of larger diameter, and having a more sluggish flow, would, if its overflows acted as soon as those on the steep sewers, discharge into the river a large quantity of very foul sewage.

23510. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—The configuration of the land is a most important factor in determining the point at which overflows shall come into operation.

23511. Should storm overflows be fixed or movable?—Where practicable the weir of an overflow should be a fixed one, but of such construction that it could be easily regulated to suit an increasing quantity of sewage. I have in mind two cases of districts (one of them recently added to the city) which were formerly drained into brooks, but are now being sewered. In these cases overflows are being provided with weirs at heights suitable for present requirements. The districts, however, are rapidly increasing, and in a year or two the weirs will have to be altered, otherwise the overflows would commence to act too soon.

23512 Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight while in others this would not be the case?—The size and nature of the stream into which storm sewage passes is again an important factor, and the possibility suggested is a real one.

23513. What happens to the road water in the portion of the city which is drained on the separate system?—Although only practicable to a small extent, where it can be done, gullies taking surface water from roads are connected direct to rivers and streams, or into storm water drains, such gullies being properly trapped and having dirt boxes to intercept any detritus.

23514. Could you give us an analysis of a typical sample of your road water during the early period of a storm, or any information as to its bacteriological condition?—I have had analyses made which will be handed in. (*See* Mr. Haworth's evidence.)

23515. Do you consider that in certain circumstances this liquid should be purified?—I do consider that in certain circumstances road water should be purified. For instance, if it comes from streets where there is large traffic and manure is lying about, or where during certain hours garbage and other market refuse is scattered.

23516. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers, bearing in mind initial outlay as well as cost?—Provided that there are adequate opportunities of passing the storm water into rivers and streams, the advantages of a separate system of sewers are better felt in a flat district than in a hilly town; also, if a separate system is to be carried out successfully and without undue expense it should be commenced when a district is being laid out. Sheffield is an old town, and for this reason alone the cost of providing a separate system would be entirely prohibitive, besides being unfair to owners of estates likely to be developed for building purposes, who, compared with those who had already laid out their land, would be at a disadvantage in the matter of cost if they had to provide double sewers. In a flat town, where probably the sewage would have to be pumped to the sewage works, a separate system would ensure that a minimum quantity was pumped, and the storm water would be passed direct to the rivers or streams instead of having to be pumped to the works and treated. During the time I acted as Deputy Engineer to the Leicester Corporation a considerable district of that town was sewered on the separate system under the late Mr. Joseph Gordon. The work was done most thoroughly, and very careful observations were made of the results. All the sewage and storm water from that particular district passed a certain point, so that by means of gaugings it was possible to determine the exact quantity of sewage and storm water which was received into the respective sewers. The proportion of storm water which entered the storm sewer was found to be about 50 per cent. and included all the rain water, except that which fell on the back part of the roofs and upon the yards of the houses. That which fell at the back was taken into the foul sewers, because it was thought that if duplicate pipes were laid up all the passages there might at some future date be mistakes in making connections, with the result that foul drainage might get to the rivers, and my subsequent experience has proved that this was not an unnecessary precaution. It is difficult to speak generally as to the advantages or otherwise of a separate system, as before giving an opinion one should be acquainted with all the circumstances of the case. In a new scheme dealing with a flat district it might be found more economical to adopt a separate system, while in an old town the cost would render this impracticable, and if the gradients were good the benefit to be received would be very much less than where there was little fall.

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23517. Is your sewage settled, and, if so, how—*i.e.*, by quiescent settlement or continuous settlement—and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—In the experiments conducted at Sheffield both quiescent and continuous settlement have been tried. In the first case two or three hours are allowed, in the second the sewage takes about eight hours to pass through the tanks. Continuous settlement is being adopted for the new scheme. The tanks in both cases have been sludged at least once per week. Analyses of the tank liquors will be furnished. (*See* Mr. Haworth's evidence.)

23518. What time would be necessary for you to gain a good tank liquor containing, say, no more than 8 parts per 100,000 of suspended solids from your sewage (without the addition of chemicals) by quiescent settlement and by continuous flow settlement?—Two to three hours by quiescent settlement and eight to twelve hours by continuous flow settlement, provided that the sludge be removed frequently from the tanks.

23519. Do you prefer to use settlement tanks in series or in parallel?—I prefer to use settlement tanks in parallel. This is a simple process, and, provided there is length enough to ensure the necessary settlement, passage through a single tank is sufficient. The average length of the tanks I have designed is 221 ft. for one portion and 260 ft. for the remainder.

23520. In the case of continuous flow tanks do you think there is any advantage in the employment of baffling boards or walls?—A decided advantage is to be gained by the employment of baffling boards and walls. In the new tanks at Sheffield scum boards will be fixed, and there will also be sunk walls near the inlet ends of the tanks. These will retain the heavy detritus at one end and facilitate the sludging. For the information of the Commissioners I hand in a section of one of the proposed new tanks which has been prepared.

23521. How is the sludging of tanks done at your works, and what is the character of the sludge? Does any nuisance attend the operation, and, if so, is it serious? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from the tanks?—In the case of the existing precipitation tanks sludging is carried out twice or three times daily. The sludge, which contains 95 per cent. to 97 per cent. of water, is passed through a valve in the floor of each tank to the sludge culvert. No nuisance attends the operation. The sludge is pumped from the culvert and stored for several weeks in shallow ponds or lagoons, with the object of reducing the proportion of

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moisture as far as possible. It is then conveyed by rail in special wagons and tipped upon land belonging to the Corporation, situate about six miles from the sewage works. The percentage of moisture when the sludge is taken away varies from 80 to 85. The liquid draining from the sludge stored at the works flows back, and is again treated with the incoming sewage. At the tip the drainage finds its way into a well, from which it is pumped by hand and treated on a bacteria bed. It is expected that the new settling tanks will have to be sludged about once a week. I should add that the sludge from an experimental septic tank at the works when drawn off was most offensive, and the gases evolved caused great difficulty and inconvenience to the men engaged.

23522. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—The heavy portion of the suspended matter should, in my opinion, be removed before the sewage is allowed to enter the settling tanks. This is done in Sheffield by means of catch pits and screens.

23523. What is the manurial value of the sludge, and will farmers take it?—The manurial value of the sludge is small, and farmers will not take it. They do, however, take as a gift the refuse from the catch pits, which contain offal, settlements from bone washings, etc.

23524. Are there any chemical poisons in it?—No.

23525. Do you find any nuisance from the treatment of sewage in settlement tanks? Have any complaints been made?—No nuisance has been experienced from the treatment of sewage in the experimental settling tanks.

23526. You have had experience of the chemical treatment of sewage?—Yes. The works at Sheffield were designed for lime precipitation, and these have been under my charge for more than twelve years. I also had experience in Leicester of precipitation works, which I believe were the first of their kind in England. They were constructed in 1854, and designed by Mr. Thomas Wicksteed.

23527. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—So far as lime treatment is concerned, the experiments for the treatment of the effluent upon contact beds were a practical failure.

23528. Have you tried various chemicals?—No other precipitant than lime is used.

23529. What is the most effective way of adding chemicals?—In order to ensure perfect slaking the lime is stored for at least three weeks before use. It is then carried to circular mixing machines, in which it is mixed with sewage and well churned by rotating arms. From the mixing machines the milk of lime is discharged into channels through which the whole of the sewage intended for the precipitation tanks must pass, and in these channels there are baffling walls to ensure thorough mixture. This method has always proved satisfactory, and I do not know of one more effective.

23530. What length of time does the sewage remain in the precipitation tanks?—When possible, the sewage remains in the precipitation tank for about 45 minutes, but when the quantity to be dealt with is above the normal this period has to be reduced.

23531. Do you find it necessary to add further chemicals to the sludge before it can be dealt with?—No.

23532. What is the manurial value of the sludge obtained by the chemical precipitation of the sludge, and will farmers take it?—What I have said as regards the sludge from settlement tanks applies also to the sludge from the precipitation tanks.

23533. Does the sludge from the precipitation tanks contain any chemical poisons?—None have been discovered.

23534. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—No nuisance arises during the treatment of sewage in the precipitation tanks. Complaints have been made, but on investigation these have been found to be due to the emptying of the catch pits.

23535. As regards septic tanks, how should they be shaped?—I consider the best shape for a septic tank is a long rectangle. The floor should be a sloping one with the greatest depth at the inlet end—this in order that the sludge may be collected at the earliest moment in a position least liable to disturbance by the flow of sewage.

23536. Should the tanks be divided into sections?—As in the case of settling tanks, I think sunk walls are desirable to prevent the sludge from being carried forward.

23537. Should they be used in series or in parallel?—In my judgment it is sufficient to pass the sewage through a single tank of suitable length.

23538. Is a scum necessary or desirable?—Not that I am aware of.

23539. Should a septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—To cover a large septic tank installation would be an exceedingly costly matter, and at present I am not aware of any advantage to be gained which would warrant the expense.

23540. What do you consider the best arrangement for the "feed" and "draw-off"?—Both inlet and outlet should consist of a narrow slit across the whole length of the end wall of the tank, the inlet in a position well below the surface. This shape tends to secure a broad, slow-moving stream which has the least liability to disturb sludge.

23541. At what rate is sewage, as a matter of custom, passed through your septic tanks?—A volume of sewage equal to the nett capacity of the tank is passed through in about 24 hours. It should be added that the tank is only an experimental one of 50,000 gallons capacity when clear of sludge.

23542. What is the most advantageous rate of flow through septic tanks?—The answer to that must depend largely upon the strength and character of the particular sewage to be dealt with. From 12 to 24 hours should be sufficient, and I do not consider that at the 12 hours' rate there should be any undue disturbance of sludge. The rate should be as rapid as is consistent with the removal of a maximum quantity of suspended solids. I should like to qualify this answer by adding that my opinion is based only on the working of the small experimental tank at the Sheffield works.

23543. Is it possible to "over-septicise" a sewage, and, if so, for what reasons and how is the "over-septicising" brought about?—It is possible, and when sewage is allowed to remain too long in the tank the effluent is not so suitable for treatment on contact beds.

23544. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?—The Sheffield tank has been worked for long periods without sludging, but the accumulation should not be allowed to go on so long that sludge rises in the tank and is carried out with the effluent.

23545. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—The septic tank sludge has been found much stiffer than that in other tanks. It has been disposed of in the same way as the other sludge. It is more objectionable in its character, and the work of removal is offensive.

23546. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank?—Yes.

23547. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—I do not consider a

septic tank system suitable for dealing with storm water sewage.

23548. If storm sewage were passed through a septic tank would this cause an increase in the amount of suspended solids issuing from the tank?—If the rate of flow was increased I anticipate there would also be an increase in the amount of suspended solids issuing from the tanks. At the same rate of flow, passing storm water through the tank instead of sewage, probably the proportion of suspended solids would be decreased.

23549. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—No.

23550. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor?—I have not found that septic tank liquor is more easily treated than settled sewage, but it is more suitable for treatment on contact beds than chemically precipitated sewage. Experiments with quiescent and continuous flow settlement have been made side by side with the septic tank treatment, and the settled sewage treatment has shown the following advantages:—(1) Settlement gives a tank liquor containing a smaller percentage of suspended solids with more ease and certainty than septic tank treatment. (2) A larger volume of sewage can be treated with the same tank capacity. (3) There is less difficulty in dealing with the sludge produced, the quantity being a small one at frequent intervals, whereas in the case of septic tanks it is usually a large quantity with long periods between each operation. (4) The sludge is much less offensive than that from septic tanks. (5) The liquid portion of the sewage is frequently made more impure and difficult to treat by contact with the products of the digestion of the sludge.

23551. Have you any data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints?—No.

23552. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—The working of the experimental tank has given rise to complaints from those engaged about it, and I am afraid that if the system was extended to deal with the whole of our sewage there would be more general complaints.

23553. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered?—I think it very desirable that suspended solids should be removed as far as practicable before filtration.

23554. How do you consider that the removal of suspended solids can best be effected?—By means of catch pits and settling tanks.

23555. Have you any experience of any mechanical device or any special tanks for freeing liquor of suspended matter before delivering it to filters?—No.

23556. What, other, if any, method of dealing with tank liquor before delivering it to filters do you regard as necessary or advisable?—If there is sufficient provision of catch pits and settling tanks I do not think any other method is necessary.

23557. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement. I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis. Kindly include the following methods so far as you have experience of them:—Quiescent settlement without chemicals; quiescent settlement with chemicals; continuous flow settlement without chemicals; continuous flow settlement with chemicals; septic tank treatment?—From the point of view of initial capital expenditure I believe the best form of settlement to be quiescent settlement without the use of chemicals. This, however, is not practicable in Sheffield, except by pumping, for although the town is hilly the district in which the works are situate is flat. Continuous flow settlement, also without chemicals, has therefore been decided upon. I consider that either of these methods is cheaper than septic tank treatment in arriving at a given result, and in neither case do I think there would be difficulty in the subsequent purification of the tank liquors, nor would there be much difference in the annual cost. With regard to the question of nuisance, this would be more likely to arise with septic tanks than by either of the other methods I have mentioned. The sludge from septic tanks is more offensive in its character than that from settling tanks, though perhaps less in quantity compared with the volume of sewage. It is quite likely that one method may suit some kinds of sewage and that another would be preferred for others. This, however, would depend upon the factors in each case, and I would not care to fix a rule.

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23558. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—Assuming that reference is made to the walls of the tank, before deciding whether building materials should be used it would be necessary to take into consideration the area and price of the land obtainable, whether any source of water supply might be affected, also the nature of the ground—whether impervious clay could be utilised, etc. In the case of Sheffield, where the land available is limited in extent and expensive to purchase, the tanks will be constructed with concrete walls and floors.

23559. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency? If so, what limits do you think are permissible?—Yes. Contact beds with a depth of 5 ft. have been in use here about six years with satisfactory purification. I should not recommend a depth much in excess of 5 ft., as with such beds there would necessarily be more danger of incomplete aeration. Beds with a depth of 3 ft. to 4 ft. would present less difficulty in this respect. For the new beds 4 ft. of filling is proposed.

23560. What do you consider is the most convenient size for a contact bed?—In a small scheme the size of contact beds must be governed to some extent by the quantity of sewage. The size should, if possible, be such that filling can be carried out within one hour. For a large scheme I consider beds with an area of about half an acre and a depth of from 3 ft. to 4 ft. very convenient to work. The capacity should in any case be such that the withdrawal of a single bed from use for purposes of rest does not seriously interfere with the capacity of the works.

23561. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—The materials which have proved satisfactory are (1) hard clinker from steel works; (2) refuse destructor clinker; (3) screened boiler clinker. All of these are only slightly disintegrable, and several years' work has little effect upon them. Coke has proved inferior to these materials, as it is more liable to disintegration.

23562. What size should the filtering material be, and should it be graded in the beds?—The best results have been obtained from graded beds. Experimental beds 3 ft. deep, graded as follows, have given a satisfactory effluent from settled sewage:—Top layer 3 in. thick, ¼ in. to ⅜ in. gauge; 9 in., ¾ in. to ½ in. gauge; 24 in. 1½ in. to ¾ in. gauge. The material used was furnace clinker. Distribution channels should be cut in the material forming the top layer and lined with fine screenings.

23563. How should the bottom of the bed be constructed?—Where a natural bottom is not permissible I should recommend the use of concrete laid with a slight fall towards the outlet. The under drains should be open-jointed pipes or channels formed in the concrete bottom, with loose perforated covers. The under drainage should, if possible, be so arranged

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that when the emptying of the bed has been completed to the normal point the pipes or channels still remain full of effluent; otherwise when the bed is refilled the unpurified tank liquor will first fill these pipes, and their contents, which will never be properly purified, will deteriorate the effluent.

23564. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—Yes.

23564.* What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary beds and for secondary beds?—Primary beds: Eight-hour cycles, namely, filling, one hour; standing full, one to two hours; emptying, one to two hours; resting to complete eight hours. Three fillings per day may be given to a bed in an active condition, but in the early stages a bed should be worked more lightly, and might be allowed to stand full for a longer time. Secondary beds: Filling, one hour; standing full, one hour; emptying, one to two hours; resting to complete eight hours. For short periods secondary beds can be filled four times per day, and the resting periods shortened without detriment. Both primary and secondary beds should also be rested for 24 hours in each week, and in cases where signs of inefficiency appear extra periods of rest should be given. These periods would no doubt require modification according to the nature of the sewage under treatment.

23565. How should contact beds be filled and emptied?—Contact beds should be filled as steadily as possible, allowing the sewage to spread evenly over the surface without disturbing the filtering material. Emptying should also be performed steadily, otherwise solid particles are carried out of the bed in the effluent. After considerable experiment I am of opinion that the best means of distribution is by means of surface channels.

23566. Have you had experience of automatic gear for filling and emptying contact beds?—The question of automatic gear has been considered, but I have not adopted it. The satisfactory working of automatic filling and emptying apparatus must largely depend upon the sewage having uniform flow and strength.

23567. What amount of tank liquor per cubic yard of filtering material can in practice be properly treated in a primary contact bed in 24 hours?—On the basis of the method of working I have described, 120 gallons per cubic yard per day can be treated upon beds which have been in use from three to four years. When the beds are new the quantity which can be dealt with is somewhat larger. The amount must vary with the quality of the tank liquor, *i.e.*, if the season is a very dry one the sewage will be stronger, but less in volume, therefore it would not be necessary to fill the beds so often and more time could be allowed for purification, which with the stronger sewage would be necessary.

23568. What amount of liquid from a primary bed can in practice be treated per cubic yard of filtering material of a secondary bed in 24 hours?—Speaking generally, on the basis of three fillings per day the secondary contact beds would have a capacity of about 160 gallons per cubic yard, as compared with 120 gallons for first contact beds.

23569. Can these quantities be increased by more frequent filling and emptying in times of storm without impairing the efficiency of the beds or the quality of the effluents?—The Sheffield beds have for short periods been filled more than the usual number of times without apparent injury or deterioration in the quality of the effluent. I therefore think it probable that the quantities given could be temporarily increased in times of storm without impairing the efficiency of the beds or the quality of the effluent. This question has not been closely investigated.

23570. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent? If so, we should like to know what tank liquors you refer to, and what effluent you are regarding as satisfactory?—Speaking of a tank liquor similar to that represented by the analyses handed in, and assuming that the outfall is a river of fair size, I am of opinion that treatment by single contact is sufficient. With such a liquor single contact usually gives an effluent approximating to the standard of the West Riding Rivers Board.

23571. At what rate or rates do primary contact beds and secondary contact beds lose their water-holding capacity?—I hand in tables showing the result of observations of about five years' working of both first and second contact beds. These particular beds were noted, because they were of watertight construction, and therefore more accurate gaugings were possible than was the case with the earthern tanks. The capacity of the empty tank to the filling point (carefully marked) was 47·5 cubic yards (8,022 gallons) for the first contact bed, and 52·7 cubic yards or 8,900 gallons for the second. A curve has also been prepared and is produced, which, together with the tables, will illustrate the results.

TYPICAL EXAMPLES OF GAUGINGS OF A 1ST CONTACT BED.

Date.	Capacity of Bed in Gallons.	Number of Fillings.	Water Capacity (empty tank =100).
1900.			
July 23rd -	4,555	1	56·7
July 25th -	3,772	5	47·0
Sept. 5th -	3,292	122	41 0
Dec. 5th -	2,778	392	34·6
1901.			
March 4th -	2,336	628	29 4
June 10th -	2,301	858	28·6
Sept. 2nd -	2,180	1,064	27·1
Dec. 3rd -	2,180	1,224	27·1
1902.			
March 4th -	2,021	1,439	25·1
June 3rd -	1,980	1,673	24·6
Sept. 2nd -	2,013	1,907	25·0
Dec. 2nd -	2,013	2,114	25 0
1903.			
March 3rd -	1,744	2,331	21·7
June 2nd -	1,785	2,548	22·2
Sept. 7th -	1,551	2,800	19·3
Dec. 7th -	1,518	3,014	18·9
1904.			
Feb. 15th -	2,088	3,177	26·0*
March 7th -	2,104	3,231	26·2
June 6th -	1,920	3,465	23·9
Sept. 5th -	2,020	3,699	25·1
Dec. 5th -	1,971	3,915	24·5
1905.			
April 3rd -	1,712	4,221	21·3

* After turning material completely over.

TYPICAL EXAMPLES OF GAUGINGS OF A 2ND CONTACT BED.

Date.	Capacity of Bed in Gallons.	Number of fillings.	Water capacity (empty tank = 100).
1900.			
Aug. 11th	4,320	1	54·1
Aug. 13th	7,378	5	49·1
Sept. 5th	4,229	66	47·6
Dec. 5th	4,021	338	45·1
1901.			
March 4th	3,962	573	44·5
June 10th	3,932	802	43·0
Sept. 2nd	3,584	1,018	40·2
Dec. 3rd	3,408	1,178	38·2
1902.			
March 11th	3,344	1,394	37·5
March 18th	3,611	1,405	40·5*
June 3rd	3,507	1,603	39·4
Sept. 2nd	3,416	1,837	38·3
Dec. 2nd	3,277	2,044	36·2
1903.			
March 3rd	3,513	2,261	37·2
June 2nd	3,258	2,478	36·6
Sept. 7th	3,308	2,730	37·1
Dec. 7th	3,118	2,944	35·0
1904.			
March 7th	2,935	3,161	32·9
June 6th	2,988	3,395	32·8
Sept. 5th	2,718	3,629	30·4
Dec. 5th	2,790	3,835	31·3
1905.			
April 3rd	2,627	4,123	29·5

* Material completely turned over on March 12th.

23572. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed or to the fineness or coarseness of the material of the bed, or on what does it depend?—In my experience the net loss in capacity is not in direct proportion to the volume treated. The amount of suspended solids contained in the liquid put into the bed is an important factor, but there are other matters to be taken into consideration.

23573. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost?—I have only had small quantities washed as an experiment, and this by hand, but I think it very probable that washing on a large scale could be satisfactorily carried out within a practicable limit of cost.

23574. How can the capacity of contact beds be best maintained?—Firstly, the greatest care should be taken to intercept suspended solids as far as possible; secondly, the distributing channels should be lined with very fine material as a further means of intercepting suspended solids which may pass the settling tanks, and these channels should be frequently cleaned; thirdly, any falling off in capacity should be carefully noted, and a period of rest given to the bed affected.

23575. Do you find any chemical poisons in your final effluent?—No.

23576. Is the first flush of effluent from either set of beds ever putrescible?—At times the first flush from the first contact beds is slightly putrescible. This is probably due, at any rate to some extent, to the fact that the underdrains get filled with tank liquor as I have described in dealing with the construction of the bottom of contact beds, and might be prevented by arranging the underdrains as there suggested.

23577. Do you find that by increasing the number of fillings in storm times or other times the amount of suspended solids is increased?—In the experiments carried out by me this difficulty has not arisen, because the number of fillings has not been increased in times of storm. Nothing but sufficiently settled sewage should be allowed to pass on to the contact beds.

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23578. May contact beds in times of storm be used as streaming filters without detriment to their customary efficiency, and, if so, do you think there are advantages in so working them?—I have tried this for short periods only without any apparent detriment. The storm water was very dilute.

23579. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre per 24 hours in ordinary times and in storm times?—As the present contact beds are of less permanent construction than those included in the new scheme, I had probably better give the estimate for the latter. The number of beds proposed is 60, with a total area of about 30 acres, and the estimate, including material, is £133,767. This does not include feed conduits. Six experimental beds were laid down about the year 1899. There are three first contact beds with an area of filtering material of about 5,000 square yards, and three secondary beds with a similar area of 4,500 yards. These tanks are roughly constructed with natural bottoms, and the excavated material was used for the tanks. The filling was coke, and the approximate initial cost £3,000 for six beds. Since then other experimental beds have been constructed, but not on so large a scale.

The present contact bed installation at the Sheffield works only deals with a proportion of the sewage, and there has been no variation in the quantity treated per acre per 24 hours either in ordinary times or in case of storm, except for purposes of experiment. Sewage is treated both by single and double contact beds, the depth varying from 3 ft. to 5 ft.

23580. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—No nuisance has been created, and no complaints have been received.

23581. Have you had any experience of continuous or percolating filters?—No experiments with continuous or percolating filters have been carried out in Sheffield except that, as I have previously mentioned, the contact beds were used for short periods as streaming filters. I have gone into the question of percolating filters, and my conclusion is that such a system would not be satisfactory for us. I may say, generally, I do not think sewage could be satisfactorily treated in percolating filters without some preliminary tank treatment.

23582. Are you able to make any comparison of the cost and relative advantages of contact beds and percolating filters?—As a result of my inquiries I have formed the opinion that contact beds are preferable. They are both cheaper and simpler than percolating filters. Less fall is necessary, and this is an advantage in flat places. The mechanical appliances which are considered necessary for percolating filters are unnecessary for contact beds, and, judging from the analyses, less suspended matter would be carried out by the effluent from a contact bed than from a percolating filter. The results from contact beds are so good and the expense of working is comparatively so small that I do not see where percolating filters can give any advantage which would compensate for the additional expense involved and want of simplicity.

23583. Do you know whether the chance of nuisance is any greater with one form of filter than with another?—I have not had the opportunity of giving the continuous observation to percolating filters that would be necessary to enable me to say what risk of nuisance there may be in their use, but no nuisance arises from contact beds as worked in Sheffield.

23584. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor or tank liquors could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds?—No.

23585 Have you had any experience of storm water filters?—So far, storm water filters have not been used in Sheffield.

23586. You are unable to say, then, whether storm water filters lose any of their efficiency by only being used intermittently at long intervals?—Unless storm water filters were kept regularly fed as described in my answer to an earlier question (No. 23507) I do not

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think there would be any effectual bacteriological purification.

23587. Have you any practical suggestions to make for disposing of sludge?—The sludge removed from the catch pits at Sheffield, which consists of sewage screenings and material from detritus tanks, is taken by farmers for use as manure without payment. It is not found practicable to make any use of the sludge from the precipitation tanks, but when the settlement tanks are in work it may be found that the sludge collected in them is of more value, as it will not contain a considerable proportion of lime, as is the case in sludge from precipitation tanks. No attempt has been made to dispose of the septic tank sludge (which bears a very small proportion to the whole) separately from the other sludge produced. Speaking generally, I do not know any be ter way than that adopted of disposing of sludge, except at excessive cost. Probably the sludge from a small work in a country district could be utilised for manurial purposes, but where the quantity is very large a properly-managed tip seems to be the best solution of the difficulty. This method has been in operation in Sheffie'd about 12 years.

23588. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?—I have not tried any other method.

23589. What, in your opinion, constitutes a good effluent?—What constitutes a good effluent must depend very largely upon the character and volume of the stream into which such effluent is passed. Speaking generally from an engineer's standpoint, and leaving out of the question very small streams which are entirely free from pollution, and badly-polluted streams, I consider that all effluents ought to be non-putrefactive and of such a degree of purity that they will at any rate not have a deleterious effect upon the stream into which they pass.

23590. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—In the matter of suspended solids I am of opinion that contact beds would give a superior effluent.

23591. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—The most important test seems to me to be that for putrescibility. This is largely a chemist's question, but I have always recognised the advisability of keeping up a regular system of tests, not only in the matter of analyses, but also for putrefaction. A chemist and his assistant have for some years formed part of the staff of my department, and are constantly engaged in this work.

23592. Is one standard for all effluents passing into non-potable streams possible and desirable?—I consider that a single standard for all effluents passing into non-potable streams is very undesirable.

23593. How should a plurality or series of standards be formulated?—The standard of purity of an effluent should have some relation to the condition and volume of the stream into which it is turned. If a hard-and-fast line is laid down this would mean, to quote an instance (although the comparison is rather against ourselves), that York—with a population equal to about a quarter that of Sheffield, emptying into the Ouse, a river with a much greater flow than the Don—would be required to give an effluent as pure as that of Sheffield, and this notwithstanding that their outfall is little above the tidal limit. Looking at the matter from the opposite point of view, some of the smaller districts in the watershed of rivers or streams emptying into the Don have their own works, the effluent of which is discharged into very small streams, and if a single standard is to be enforced they would turn out an effluent of no greater purity than Sheffield, although instead of emptying into a river of fair size their effluent would at some seasons of the year practically form the whole flow of the stream into which it is supposed to empty. If a central authority to deal with sewage purification matters is established I think it might very usefully discriminate as to the standard of purity to be required from works dealing with the sewage of different districts emptying into rivers and streams of varying size and condition.

23594. How far do you consider it advisable for a sewage installation to be worked automatically?—I do not consider it advisable for ordinary sewage installations to be worked automatically for the reason already given—that, generally speaking, satisfactory automatic working must depend upon a uniform flow and quality of sewage.

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Mr. JOHN HAWORTH, F.C.S., Chemist in Charge of the Sheffield Corporation Sewage Works, called in; and Examined.

23595. (*Chairman.*) You are Mr. John Haworth, Fellow of the Chemical Society, and Chemist at the Sheffield Corporation Sewage Works?—Yes.

23596. Do you find that the trade effluents at Sheffield interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise? If so, would you kindly tell us what your difficulties are?—I hand in a Tabular Statement showing briefly what the effect is as regards each kind of trade waste.

TABULAR STATEMENT.

Nature of trade waste and quantity.	*Effects on lime precipitation process.*	*Effects on settling tanks and contact beds.*
Brewery waste. 20,000 to 30,000 gallons per week and much fresh cooling water.	Hops and waste yeast in suspension pass into the effluent channels.	Hops and waste yeast pass from tanks to contact beds. Sudden rushes of waste occur at times producing a liquid, treated only with difficulty.
Iron pickle. 50,000 to 100,000 gallons: per week of strong pickle.	This waste is generally strongly acid, and large volumes are discharged suddenly. The liming arrangements are temporarily disorganised and frequently sewage passes the liming house insufficiently limed before the presence of the waste can be observed.	Great care is necessary to avoid discharges of strong acid pickle upon the contact beds, the acid being sufficiently strong at times to cause sterilisation. If diluted, the waste merely deposits iron-hydroxide on the material of the contact beds, but causes no other inconvenience.
Tripe-dressers, fell-mongers and skin-dressers wastes. Ten to twelve tons of offal per week.	The liquid portion of these wastes is usually diluted, so as to cause little inconvenience. The solid portion deposits in the catch-pits, channels, etc.	
Oils and tarry matter. Irregular discharges occurring two or three times per year of 2000 to 3000 gallons of whale oil.	Necessitate skimming from tanks, etc., with much labour.	

Nature of trade waste and quantity.	*Effects on lime precipitation process.*	*Effects on settling tanks and contact beds.*
Tannery waste. 10,000 gallons in two or three discharges per week	In combination with iron salts, this waste produces "Ink" upon which the precipitation process has no effect. Sudden discharges of the waste together with iron pickle render it impossble to produce a satisfactory tank effluent.	The inky liquid is incompletely decolorised by a single contact and oxidation is by no means complete. A second contact usually removes the colour, and non-putrescible effluents can be obtained.
Ammonium sulphate waste.	The precipitation process is incapable of dealing with this waste.	The great difficulty with this waste is due to the discharge of large volumes suddenly, thereby producing a very concentrated liquid for treatment.
Grinders and stone cutters waste. Slack washings and grain washings. Including 10 to 12 tons of small coal deposited in catchpits per week.	Increase deposits in catchpits, but are not otherwise detrimental.	

23597. In dry weather what is the average amount of suspended matter in the Sheffield sewage, and what are the highest and lowest figures, in parts per 100,000 ?—The average amount is 50·23 parts per 100,000 ; highest figure, 138·57 ; and lowest figure, 18·71.

23598. What is the physical character of these solids ?—The solids in suspension in dry weather contain—Small coal, sand from grinding operations, iron oxide, paper fibres, vegetable debris, flocculent matter, with fat and offal among the grosser solids.

23599. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and winter ?—Yes. The analyses are :—

	Parts per 100,000.		
	Oct. '02 to Mar. '03.	Apr. '03 to Sept. '03.	Oct. '03 to Mar. '04.
Oxygen absorbed in 4 hours - - -	7·13	7·50	6 63
Ammoniacal Nitrogen -	2·75	3·02	2·05
Albuminoid Nitrogen -	·71	·82	·74
Chlorine - - -	11·28	12·14	10·06
Number of samples -	46	30	30

23600. How do you think "strength" of sewage as affecting purification is best expressed or measured ?—For practical purposes the determination of oxygen absorbed in four hours, and albuminoid nitrogen indicate the strength fairly satisfactorily, as the amount of purification necessary, and a general idea of the nature of the impurities are thereby indicated.

23601. Have you any information as to the bacteriological condition of the sewage in dry weather and in storm times ?—No.

23602. Are there any chemical poisons in your sewage ? If so, what are they, and to what extent do they occur ?—Free acids and sulphocyanides are present periodically.

23603. Is your sewage always alkaline ?—The sewage is usually very slightly alkaline, except during discharges of acid wastes such as iron pickle, from manufactories near the Sewage Works ; the sewage then gives an acid reaction for short periods.

23604. Do you find that the amounts of suspended solids are increased or diminished in times of storm ; and can you give the Commission the figures at the end of each hour during a storm of some hours duration ?—I hand in a Table giving the results of determinations made during a storm.

Suspended Solids in Sewage during a Storm on February 13th, 1905. Rainfall : ·11 Inc.

Time.	Parts per 100,000.		
	Total Solids in Suspension.	Mineral.	Organic and Volatile.
10.50 a.m., before rain - - - -	59·24	9·92	49·32
11.50 a.m. - - - - - -	60·24	5·04	55·20
12.50 p.m. - - - - - -	67·12	13·20	53·92
1.50 p.m. - - - - - -	170·07	76·62	93·45
2.50 p.m. - - - - - -	125·93	50·55	75·38
3.50 p.m. - - - - - -	133·46	63·03	70·43
4.50 p.m. - - - - - -	101·20	67·33	33·87
5.50 p.m. - - - - - -	100·60	47·06	53·54
6.50 p.m. - - - - - -	97·93	26·93	71·00
7.50 p.m. - - - - - -	41·73	15·33	26·40
8.50 p.m. - - - - - -	40·06	18·66	21·40
9.50 p.m. - - - - - -	26·26	15·06	11·20

This table indicates the general variation in the amounts of suspended solids during a storm. The first determination was made before the effects of the rain were observed at the Works, and the final one when the storm overflow nearest the Works ceased to operate.

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23605. Could you give us an analysis of a typical sample of your road water during the early period of a storm?—Yes.

ANALYSES OF ROAD WATERS FROM GULLIES TAKEN 2ND MAY, 1905.

Results expressed in parts per 100,000.

Nature of Sample.	Oxygen absorbed in 4 hours at laby. temp.		Ammonia (as N.)		Chlorides (as Cl.)	Solids in Suspension.			Solids in Solution.		
	Total.	Solution.	Free and Saline.	Albuminoid.		Total.	Loss on ignition.	Ash.	Total.	Loss on ignition.	Ash.
Granite paving from Wicker - -	11·99	3·04	0·082	0·469	2·0	46·57	14 07	32·50	30·71	14·57	16·14
Wood paving from Castle Street -	7·59	3·14	0·588	0·489	2·6	28·57	13·21	15 36	41·43	21·00	20·43
Castlefolds Gritstone paving in Shambles	18·63	12·71	2·588	10·540	6·6	65·00	39·33	25·67	—	—	—
Tar Macadam from Stanley Street -	38·61	11·70	2·117	1·471	5·0	254·28	98·64	155·64	91·72	38·86	52·86

23605*. What is the character of the liquid part of the sewage in storm times?—Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—The liquid portion of the sewage in storm times frequently becomes very weak after the first flush. Comparative analyses are given of samples taken each hour during each twenty-four hours in wet weather; the hourly samples being mixed for analyses. Similar analyses of samples taken during dry periods are given. The suspended solids were removed by settlement in tanks only.

Analyses of Septic Tank Liquors.

Parts per 100,000.

In Wet Weather.						In Dry Weather.				
	Rainfall in inches.	Oxygen absorbed in 4 hours.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Chlorine.		Oxygen absorbed in 4 hours.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Chlorine.
1900.						1904.				
Dec. 2	—	3·47	—	—	8·5	May 4	4·85	2·6	·53	9·1
„ 3	—	3·60	—	—	8·7	„ 9	5·71	2·1	·32	12·7
„ 30	—	3·70	—	—	7·7	„ 11	5·80	2·3	·63	12·6
„ 31	—	1·90	—	—	4·8	„ 18	6·45	2·8	·66	12·3
1901.						June 7	5·65	1·5	·28	12·6
Jan. 28	—	2·60	—	—	7·7	„ 14	4·65	1·9	·46	12·3
„ 29	—	2·55	—	—	8·3	„ 16	4·90	2·9	·32	11·4
„ 30	—	2·94	—	—	—	„ 22	5·07	2·3	·49	12·0
1903.										
May 3	—	2·61	2·23	·39	7·7	„ 28	4·73	2·3	·74	12·4
„ 6	—	2·37	1·29	·17	7·1	„ 30	4·75	2·6	·35	11·1
„ 10	—	1·88	·59	·14	5·3					
„ 13	—	2·25	1·76	·32	8·3					
Aug. 18	—	3·98	1·53	·32	8·4					
„ 20	—	4·53	2·70	·28	8·8					
Oct. 7	—	3·50	1·76	·39	8·5					
„ 12	—	4·01	1·53	·14	8·3					
„ 14	—	4·30	1·29	·25	8·4					
1904.										
Feb. 4	—	3·28	1·53	·35	7·3					
Average	—	3·14	1·62	·27	7·7	Average	5·25	2·3	·47	11·8

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ANALYSES OF SETTLED SEWAGE.

Parts per 100,000.

In Wet Weather.						In Dry Weather.				
	Rainfall in inches.	Oxygen absorbed in 4 hours.	Ammoniacal Nitrogen.	Albuminoid Nitrogen..	Chlorine.		Oxygen absorbed in 4 hours.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Chlorine.
1901.						1903.				
Nov. 13	—	4·63	1·64	·21	6·5	April 1	4·83	2·70	·25	11·5
,, 19	—	5·34	·82	·18	9·5	,, 5	4·41	2·82	·60	11·3
Dec. 12	—	3·00	1·11	·21	9·1	,, 19	5·44	4·94	·84	14·1
,, 15	—	1·17	1·20	·25	8·3	,, 22	5·78	2·70	·87	14·0
1902.						,, 28	5·85	2·47	·56	12·8
April 15	—	3·28	1·64	·35	5·1	,, 30	4·83	4·00	·13	10·1
Aug. 6	—	3·13	2·94	·21	—					
,, 10	—	1·75	1·29	·21	—					
Nov. 30	—	4·17	2·47	·45	5·8					
1903.										
Jan. 11	—	2·97	·94	·21	6·7					
May 5	—	2·03	·70	·10	6·0					
,, 7	—	2·45	1·17	·25	7·5					
Oct. 6	—	3·77	1·29	·25	7·1					
,, 8	—	2·95	·82	·18	6·0					
,, 13	—	3·10	·82	·21	8·5					
,, 15	—	3·04	·59	·18	6·1					
,, 20	—	2·67	1·88	·46	9·3					
Average.	—	3·09	1·33	·24	7·2	Average.	5·19	3·27	·54	12·3

23606. Would you kindly give us an average analysis of the liquid from your settlement tanks ?—The following is an average analysis of the tank liquors (settled sewage) taken during periods of six months :—

	Parts per 100,000.	
	Oct. '02 to Mar. '03.	Oct. '03 to Mar. '04.
Oxygen absorbed in 4 hours	4·14	4·33
Ammoniacal Nitrogen	2·70	1·69
Albuminoid Nitrogen	·43	·40
Chlorine	10·57	9 98
Suspended Solids (58 samples)	10·75	—

23607. Have you data to show what proportion of the suspended matter in your sewage is settled in ½-hour, 1, 2, 3, 4, 5, 6, 12, and 24 hours, if the sewage is given quiescent settlement ?—

The following is the result :—

	Parts per 100,000.
Total suspended solids	4·81
Organic and Volatile solids	3·97
Mineral solids	·84

The solids are exceedingly light, and remain in suspension for long periods.

23610. Is it possible to " over-septicise " a sewage, and if so, for what reasons, and how is the " over-septicising " brought about ?—It is quite possible to over-septicise a sewage. Sewage allowed to remain in the tank for too long a period has been found to be highly charged with sulphuretted hydrogen and other products of the decomposing sludge, and to be very difficult to treat on the contact beds.

23611. What is the amount of digestion in your septic tanks, and how do you calculate this ? How far do you find that the digestion is affected by atmospheric temperature ?—An experiment conducted as accurately as possible indicated a digestion of 32·9 per cent. of sludge.

This result was obtained from the following data :—

1. The suspended solids *entering* the tank were determined.
2. The suspended solids *leaving* the tank were determined.

ESTIMATIONS OF SUSPENDED SOLIDS IN SEWAGE.

Results expressed in parts per 100,000.

Time.	Taken 2′ 6″ below surface of No. 4 tank. 27–28 April, 1905.			Taken from surface of No. 4 tank. 10–11 May, 1905.		
	Total.	Loss on ignition.	Ash.	Total.	Loss on ignition.	Ash.
After being stirred up	20·40	4·87	15·53	57·57	33·90	23·67
,, ½hr settlement	19·86	8·62	11·24	22·00	13·43	8·57
,, 1½hrs ,,	13·14	3·61	9·53	21·43	13·04	8·39
,, 2½ ,, ,,	11·86	3·47	8·39	16·43	10·19	6·24
,, 3½ ,, ,,	9·29	1·62	7·67	16·14	9·90	6·24
,, 4½ ,, ,,	8·14	1·47	6·67	15·57	9·86	5·71
,, 5½ ,, ,,	7·29	0·95	6·24	13·43	7·72	5·71
,, 6½ ,, ,,	6·43	0·90	5·53	12·43	7·33	5·10
,, 12 ,, ,,	5·57	0·76	4·81	11·14	6·31	4·83
,, 24 ,, ,,	5·00	0·76	4·24	9·29	4·73	4·56

23608. What is the average analysis of the liquor from your precipitation tanks ?—The following is an average of 202 samples of tank effluents from the Lime precipitation process :—

	Parts per 100,000.
Oxygen absorbed in 3 minutes	1·51
Oxygen absorbed in 4 hours	2·80
Ammoniacal Nitrogen	1·09
Albuminoid Nitrogen	·152
Chlorine	10·54
Suspended solids (9 samples)	4·81

23609. What is the character of the suspended matter in such liquor ?—Determinations of 9 samples gave the following average composition of the suspended solids.

3. The quantity of sewage passing through the tank was gauged.
4. The sludge remaining in the tank at the end of the period was weighed, and the suspended solids contained in it were determined.

The scum on the tank is found to increase in thickness during the winter months, and to decrease during warmer weather, but no further observations have been made.

23612. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tanks ?—Yes, the solids begin to increase after three to four weeks, work, and in the later stages masses of lighter sludge rise, and pass out with the effluent.

23613. What amounts of suspended solids, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out,

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and at the end of the period, *i.e.*, when tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—Eight to eleven parts per 100,000 in the early stages rising to seventeen to eighteen parts per 100,000 after several months of work. The quantity is, however, very variable in the later stages, as at certain periods large quantities of solids rise in the tank and pass away in the effluent, with a temporary improvement following.

23614. Do you think it is desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered?—If so, what do you consider a practicable limit to get down to?—The suspended solids in the sewage should be reduced to eight to ten parts per 100,000 by suitable tank treatment.

23615. As regards contact beds, is one contact sufficient for the conversion of certain tank-liquors into a satisfactory effluent?—If so, what tank-liquors, and what effluent are you regarding as satisfactory?—Average tank liquors of the quality referred to previously (*see* Question 23605) can generally, by a single contact, be converted into effluents which approximate to the standards of the Mersey and Irwell Joint Committee and of the West Riding Rivers Board, and frequently when these standards are slightly infringed the effluents are non-putrescible, and do not take up dissolved oxygen from aerated water excessively.

The following average of analysis illustrates the tank liquors treated and the results produced by single contact treatment:—

	Parts per 100.000.	
	Tank Liquor.	Effluent.
Oxygen absorbed in 4 hours	4·14	1·68
Ammoniacal Nitrogen	2·70	1·44
Albuminoid Nitrogen	·43	·17
Chlorine	10·57	10·42
Suspended Solids	10·75	—
Nitrogen as Nitrates and Nitrites	—	40

The following series of incubator results, and percentages of loss of dissolved oxygen illustrate the behaviour of such effluents when mixed with well aerated water in the proportion of two of tap water to one of effluent:—

	Mixtures of two of tap water and one of effluents.		
	Incubator tests at 80 degrees Fahr. for 6 days. Oxygen absorbed in 3 minutes.		Loss of dissolved Oxygen in 24 hours at 60 degrees Fahr.
1904.	Before.	After.	Per cent.
September 26	·33	·31	58·2
,, ,,	·20	·20	38·2
,, 27	·17	·16	69·9
,, ,,	·27	·23	32·4
,, ,,	·49	·50 x	56·6
,, 28	·16	·11	11·4
,, 29	·37	·37	42·3
,, ,,	·29	·30 x	32·0
October 3	·36	·39 x	75·4
,, 4	·19	·17	28·1
,, 5	·16	·13	14·4
,, 6	·26	·20	23·2
,, 9	·28	·29 x	44·5
,, 10	·33	·33	31·8
,, 11	·11	·09	27·6
,, 14	·41	·47 p	73·6
,, 19	·20	·17	31·7
,, 20	·11	·08	12·7
,, 21	·16	·12	17·4
,, 24	·21	·21	30·2
,, 25	·30	·32 x	63·2
,, 26	·12	·10	17·6
,, 27	·10	·08	10·7
Average	·24	·23	—

p. Putrescible. x. Doubtful.

23616. Is the loss of capacity in contact beds in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed or to the fineness or coarseness of the material of the bed, or on what does it depend?—In addition to purely mechanical causes, and the effects of undigested solids, the growth of the gelatinous coating, which forms upon the surface of the material of the bed, contributes to reduce capacity. The direct effect of the amount of suspended solids can therefore hardly be determined.

23617. How can the capacity of contact beds be best maintained?—Close attention to the analytical results of the liquor treated, and of the effluents are essential, so that the proper periods of rest may be given. Falling off in nitrification, indicating reduced digestion, in the bed, and eventually undue loss of capacity, must receive careful attention.

23618. What are the average analyses of your single contact effluent and your double contact effluent?—The figures are:—

First Contact Effluents.

Oxygen absorbed in four hours	1·68	parts per 100,000
Ammoniacal nitrogen -	1·44	„ „ „
Albuminoid „ -	·17	„ „ „
Chlorine - - - -	10·42	„ „
Nitrogen as Nitrates and nitrites - - - -	·40	„ „ „

Second Contact Effluents.

Oxygen absorbed in four hours	·60	parts per 100,000
Ammoniacal nitrogen - -	·34	„ „ „
Albuminoid „ - -	·058	„ „ „
Chlorine - - - -	10·14	„ „ „
Nitrogen as Nitrates and nitrites - - - -	1·64	„ „ „

23619. What is the average amount of suspended matter in the primary bed effluent, and the secondary bed effluent? Does most of this suspended matter come out with the first flush or not?—The suspended matter is:—

First contact effluents -	3·58	parts per 100,000
Second „ „ -	1·85	„ „ „

There is slightly more suspended matter in the first flush but such solids continue evenly throughout the discharge.

23620. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a contact bed, is different from the organic matter of the suspended solids going on to that bed?—No detailed analyses have been made, but the solids are usually less putrescible and frequently in Sheffield consist largely of iron hydroxide.

23621. Is the first flush of effluent from either set of beds ever putrescible?—The first flush from first contact beds is at times putrescible but not from second contact beds. By a modification of the under-drainage as mentioned in the City Surveyor's evidence probably this could be avoided.

23622. What, in your opinion, constitutes a good effluent?—An effluent conforming to the provisional standards of the Mersey and Irwell Joint Committee for oxygen absorbed in four hours and albuminoid ammonia, would be a good effluent, and in practice I have found that effluents which slightly infringe those standards, as shown in the analyses furnished by me, are frequently non-putrescible, and therefore in my opinion suitable for discharge into non-potable streams. Such effluents should not contain more than five pts. per 100,000, of suspended solids, and should not absorb a large quantity of dissolved oxygen from well ærated water.

23623. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—I have not had much experience of effluents from percolating filters, but effluents similar to those from the Sheffield contact beds usually contain less suspended matter than those from percolating filters, are rich in nitrates, are not putrescible, hold dissolved oxygen, and support fish life.

23624. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—The oxygen absorbed in four hours and the free and albuminoid ammonia, and nitrogen as nitrates and nitrites determinations are made, from which an opinion can be formed as to the effectiveness of the treatment and the general liability to putrescence of an effluent. This opinion is further confirmed by the incubator test, and the determination of the rate of absorption of dissolved oxygen from ærated water. For the frequent checking of the quality of effluents the oxygen absorbed in four hours, the incubator and nitrate tests are found convenient and reliable.

23625. Have you tried the "æration" test, *i.e.*, the rate at which dissolved oxygen is taken up by an effluent?—Yes. Results have already been supplied to the Commission in the Monthly Tables of Analyses (*See* Appendix to Mr. Haworth's evidence), and further results have been given in answer to a previous Question (No. 23615).

23626. Could you make a short statement setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents?—Yes.

Oxygen Absorbed in Four Hours' Test.—This test is useful in indicating, approximately, the total work required to purify a sewage, and the general efficiency of the result produced.

Free and Saline, and Albuminoid Ammonia.—These determinations in combination with the above test indicate the general character of the impurities in the sewage, and the progress of the purification when applied to the effluent.

The Nitrogen as Nitrates and Nitrites determination indicates the efficiency of the process and is most valuable as an indication of the quality of the effluent, and also as to the condition of the bed.

Suspended Solids.—The determination of suspended solids is of the greatest value, as it has an important bearing upon the capacity of filter beds and the effects of effluents upon streams.

Incubator Test.—This test is most valuable in determining the liability of an effluent to become putrescent. Effluents, which bear this test successfully, are in no way liable to cause nuisance when discharged to a stream.

Rate of Absorption of Dissolved Oxygen.—This test is of great value in indicating the probable effect of an effluent upon the water of a stream to which it is discharged. An effluent which holds dissolved oxygen satisfactorily is not liable to cause further nuisance.

23627. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc.?—For practical purposes the "strength" of sewages and tank effluents is indicated by the oxygen absorbed in four hours and free, saline, and albuminoid ammonia, and suspended solids determinations. These determinations are convenient to perform, and I know of none more generally satisfactory.

23628. Now, on Question 23489, how were the contents of privies and middens and closets disposed of?—(*Mr. Wike.*) A great proportion is collected and taken to tips.

23629. They are collected by the municipal authority?—Yes.

23630. And that is done without any nuisance I presume?—Well, a minimum amount of nuisance. We have a large piece of land some distance from the centre of the town to which the contents of the privies are carted. You will see by the answer to that Question (23489) that we are gradually converting these privies into water closets. We have also two destructors at which a certain quantity of the contents of the privy middens are consumed, but not a very great proportion. It is proposed to erect two additional destructors.

23631. Then Question 23497, you say, "It is impossible for me to say what volume passes over the overflows." You could not even give us an approximate estimate?—No, on some steep gradients an overflow might come into operation, say, in ten minutes. Certain of our sewers, however, have gradients of not more than 3 ft. to the mile, and running into these sewers are others coming down steep streets with gradients of 1 in 5.

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On these steep sewers the overflows would come into operation very quickly, but those on the main sewers with flat falls might be a long time before they would operate.

23631.* Would you consider that the amount passed over the overflows was a very large amount ?—It is in times of heavy rain.

23632. Would it be half as much we will say, as the volume of the treated sewage ?—Yes.

23633. You think it would be half as much ?—I think it would be. That is, at certain of the overflows. Probably it might be convenient to explain here that the town itself is a very large one ; it is about twelve miles in length ; the altitudes vary from 100 feet above Ordnance Datum at the sewage works to 1,600 feet ; in the higher parts and inside the city boundary we get a rainfall varying from twenty-one inches at the sewage works to thirty-seven inches at the higher altitudes—a difference of sixteen inches, which would affect the overflows a good deal.

23634. On Question 23506, you say, "I mention these figures to show that a large proportion of the Sheffield sewers are comparatively new and therefore in good condition, and have gone into detail touching some of the points as evidence has been given before another Commission, based I feel sure upon a misconception of the facts." Now, what other Commission is that ?—It is the Inter-Departmental Committee on Physical Deterioration. The question was, "Is the drainage of Sheffield bad ?" The reply was "It is bad. First of all there is a large number of rubble sewers. Then there is the privy midden system." Another question was, "There being practically no main drainage ?" The reply was "Yes." The authorities of Sheffield felt they had been misrepresented, as since 1886, the Corporation have spent a sum of £429,401 in the construction of sewers, which includes £102,000 for the re-construction of thirty miles of rubble sewers.

23635. Who gave that evidence ?—The evidence was given by Mrs. Greenwood, who was formerly an inspector under the medical officer of health. There has been no opportunity of refuting this statement, and I thought it advisable to do so now.

23636. Then on Question 23527 you say, "So far as lime treatment is concerned, the experiments for the treatment of the effluent upon contact beds were practically a failure." Have you any theory to account for that ?—That would be on account of the alkalinity of the limed effluent which seemed to sterilise the contact beds. Analyses for the experiments were made at the time, and can be forwarded to the Commission.

23637. On 23543, as to the possibility of over septicising the sewage, did you make any observations on that point ?—No.

23638. But did you make enough to enable you to speak quite positively, and to say positively that it is possible to allow sewage to remain too long ?—No, I did not ; it is only my opinion.

23639. And on Question 23550 you say that septic tank liquor is more suitable for treatment on contact beds than chemical precipitated sewage. Now, can you speak quite positively as to that ?—Only from my experience at the works. It is rather a chemical question.

23640. Do you feel confident about that ?—(*Mr. Haworth.*) Yes. Such lime effluents as are at present produced at Sheffield appear to sterilise the contact beds. When an ordinary lime effluent was put upon the single contact bed it was found that the purification was practically nothing. I attributed it myself to the strong alkalinity of the effluents which contain 5 to 7 grains per gallon of free lime.

23641. And you found that as the result of several trials ; not only one ?—Yes, the experiments were going on for some two or three months when I first came to Sheffield.

23642. On Question 23573 you say you think it very probable that washing on a certain large scale could be satisfactorily carried out ; do you know anything of that practice at other places than Sheffield ?—(*Mr. Wike.*) I have seen works at Manchester and Birmingham but I do not know that they have any process for washing on a large scale at the present time.

23643. When you say you think washing on a large scale could be satisfactorily done you are only expressing an opinion ?—Yes ; I think it will be possible to do it instead of having these enormous quantities of clinker or other material to turn over from time to time. It may be possible to wash it by means of pressure.

23644. And on Question 23579 do you find that the cubic yard of the shallow beds has the same purifying effect as the cubic yard of the deeper beds ?—We have not tested the deeper beds because the first beds we made were constructed in a rough and ready way, and the test would not have been very accurate, but later tests, the results which have been supplied to you, have been conducted in perfectly water tight tanks. From the first beds we got very good results, but the beds were rather crude in construction. About 2½ acres of these beds were put down, the earth being simply dug up and made into banks ; and the bottoms drained and covered with ashes. It was a natural bottom and was found to leak ; therefore, any figures given might have been misleading ; the figures are, however, as accurate as could be taken ; and have been supplied to your Commission.

23645. On Question 23587 you seem to contemplate the possibility of sludge becoming more valuable when it is free from lime. Several people have told us that it is the lime that gives it a manurial value, but you do not find that so ?—It depends upon the land for which the sludge is wanted. Some time ago a tenant of the Duke of Newcastle, who has land which is very sandy, had a quantity of our sludge for an experiment. He wished to have it dried, but we could not do that, so the sludge remained in lumps and would not disintegrate. It is now several years since he had it and he can still trace where the sludge has been put on the land, the crops are so very green. We have a sale only for certain parts of the sludge—that taken from the catchpits which contains offal from slaughter houses. They will take this but the other we cannot get rid of.

23646. (*Sir William Ramsay.*) I should rather like to ask Mr. Haworth a question or two. I should like to ask as regards your tabular statement if the iron hydroxide which you speak of in answer to Question 23596 tends to clog the beds ; does it pass through at any time ?—(*Mr. Haworth.*) A large proportion of it remains in the bed. A portion of it passes out and deposits from the effluents after standing a few days, but the greater proportion, I think, remains in the bed.

23647. Then do you allow the effluent to subside at all in order to get rid of that ?—No, I have simply observed it in samples kept in bottles.

23648. What river do you drain into in Sheffield ?—The Don.

23649. Does it deposit there ?—No, we have not observed it.

23650. Is it a rapid river ?—Fairly rapid.

23651. It is carried down ?—It is carried down when present ; but, of course, the proportion of the bacterially treated effluent is comparatively small, as it is discharged together with the lime effluent. In the case of the lime effluent, of course, the iron is removed almost entirely.

23652. Is the reason why you use lime in order to utilise the acid ; to remove iron ?—Well partially, of course, and in order to assist the clarification.

23653. You do not require to add iron ; it is the very opposite ; you want to remove it ?—No, if we could only spread the discharges of iron over the twenty-four hours we should have quite sufficient for a suitable copperas and lime process.

23654. Are any steps being taken to obtain a regular delivery of trade effluent ?—The question of regulation is under consideration, and in one case recently the discharge of the iron liquor has been stopped, or rather it was a case in which permission was asked, and refused, and the people are now evaporating the liquor, recovering the acid and disposing of the crystals of ferrous sulphate.

23655. I suppose you would be very glad if some scheme could be adopted for distributing all these trade effluents equably over the twenty-four hours ?—It is very desirable and very necessary.

23656. In answer to Question 23597, you give the average amount of suspended matter in the Sheffield sewage as fifty parts per 100,000. How much of that is organic ?—About 50 per cent.

23657. It is just about half ?—About half, yes ; I will hand in the figures.

23658. In answer to Question 23600 you suggest the oxygen absorbed and albuminoid nitrogen as a measure of the strength of sewage, but do you get parallel results in your case at all owing to the amount of ferrous salts making the oxygen absorbed quite out of proportion to the albuminoid nitrogen ?—Yes, we do at times, but generally speaking they run fairly close together ; there are times when they are utterly out of proportion, and I should combine the two tests. I do not mean that either of them would indicate the strength alone. Albuminoid nitrogen would indicate the amount of nitrification necessary ; if the albuminoid nitrogen was low and the oxygen absorbed was high one would assume that iron pickle or some trade waste was present and that it was not a case of strong domestic sewage.

23659. Are there mineral poisons besides phenols and sulphate cyanide ?—I do not know of any.

23660. Have you tested ?—Not specially ; I have not made any special examinations for poisons.

23661. In answer to Question 23609, you speak of very light solids which remain suspended in your precipitation tanks ; have you examined those solids in particular ; do they consist of finely divided oxide of iron ?—Yes, it is largely iron hydroxide.

23662. Suspended ?—Yes, in fact all the ashes from both sewage and effluents with few exceptions are quite red with the iron.

23663. I presume that before treating your sewage in your septic tank you lime it down, do you not ?—No.

23664. You do not lime it down ?—Not at all.

23665. Is it possible to get an effluent of sulphuretted hydrogen in such enormous amounts as you have in the sewage ?—Yes, we get the iron in the case of the septic tank coming out as sulphide.

23666. But surely you never have sulphuretted hydrogen ?—In addition to that we have sulphuretted hydrogen. Bright lead plates are turned black very readily.

23667. Really, in spite of all that iron being present ?—Yes.

23668. And when it is in that state it is very difficult to treat on the contact beds I presume ?—Very difficult.

23669. Do you find the sulphide of iron gives you trouble on the contact beds ?—I find that a liquor which contains a large proportion of sulphide of iron, or which has been rather a lengthy period in the tanks—say two days—is very difficult to treat on the first contact bed. The result is that the purification is reduced very rapidly ; when the septic tank has rested for, say, a day we find the next discharge from it is very difficult to treat, and we get a reduced purification.

23670. How long did your experiment mentioned in answer to Question 23611 go on ; it deals with the digestion of sludge ?—Seventeen months.

23671. And then how often do you take samples for analyses, roughly speaking ?—Samples were taken daily, and the daily samples were mixtures of hourly samples, and they were analysed from three to four times per week.

23672. (*Colonel Harding.*) Might I on that point, Sir William, ask a question on the digestion of sludge. What do you quite mean in saying that you find there is a digestion of 32·9 per cent. of sludge ; do you mean to say that there is a digestion of that proportion of the sludge lying in the tank, or that that is the proportion of the suspended matter originally in the sewage ?—That is the proportion of the total suspended matter in the sewage.

23673. Then it is not really the proportion of digestion of what is left in the tank ?—No, it is the total digestion.

23674. Calculated upon the original amount in the sewage ?—Calculated upon the original amount in the sewage.

23675. That, of course, makes a very important distinction ?—Yes, quite so.

23676. (*Sir William Ramsay.*) In answer to Question 23622 you suggest that a good effluent is one which does not contain more than five parts per 100,000 of suspended solids, and should not absorb a large quantity of dissolved oxygen from well aerated water. I presume that means, should not putresce ?—Quite so.

23677. And you would regard that as the best test to apply to it ?—I do. In that question reference is made of the Mersey and Irwell standards. I have frequently found that effluents which do infringe slightly those standards are at the same time non-putrescible.

23678. And you regard a test for non-putrescibility as the best test ?—I think it is possible to have albuminoid matter in a non-putrescible condition as in the case of a very strong domestic sewage. I have frequently found effluents which have remained perfectly sound on incubation to infringe the Mersey and Irwell standard for albuminoid ammonia to a considerable extent.

23679. I should like to ask a question on 23626. Have you been able to arrive at an approximate ratio between the four hours oxygen-absorbed figure given by a sewage or tank liquor and the area of filter beds with a clarified sewage ? or between any one of those tests which you suggest are useful standards and the area of the filter beds required to treat the effluent ?—No, I have not gone personally into that.

23680. (*Major-General Carey.*) Question 23490, the dry weather flow, based on water supply is 8,492,000 gallons, and apparently from the record of your summer and winter flow that is nearly 6,000,000 of water from other sources which enter the sewers ?—(*Mr. Wike.*) 3,500,000 gallons I have put in my answer.

23681. Come back to my figures. Your dry weather flow based on water supply is 8,500,000 gallons. Your record of the average dry weather flow is over 14,000,000 winter and summer ?—Yes.

23682. That leaves a large balance of nearly 6,000,000 gallons to be accounted for ?—The 8,000,000 does not include the trade water.

23683. Partly trade, partly domestic, but how much of this difference of nearly 6,000,000 is due to subsoil water. It is a very large volume ?—The quantity I take is 25 gallons per head. That makes the sewage come to 10,000,000. I consider that we have got 2,000,000 gallons of trade waste, and besides that there is 3,500,000 gallons a day which we know we get from the different works in the town to make up the 15,000,000 gallons.

23684. From other sources do you mean ?—Yes.

23685. From wells ?—No, from mines and works ; several of the large works have access to the river and take water for trade purposes. It is to a certain extent pure water, but instead of going back again into the river it is turned into the sewers.

23686. In reply to Question 23490 you say a large amount of fresh water entering the sewers ought to be turned into the rivers or streams ?—Yes.

23687. Are you referring to subsoil water ?—No, a great bulk comes from the works, being taken from the river, and after passing through the works with very little pollution is discharged into the sewers.

23688. Can that volume be diverted entirely from the sewers ?—We are arranging with different works in order to eliminate this water and turn it into the rivers or streams.

23688*. And is it sufficiently pure to be turned into the river direct without treatment ?—Yes ; some if it comes from mines, brick yards, streams, etc.

23689. How is the storm sewage of Sheffield treated at present ?—Storm sewage ?

23690. Yes ?—It goes through the works—that is, as much as the works will take—and the remainder goes over the overflows.

23691. How do you treat the volume which comes to the works ?—It is passed through the tanks in the same way as the ordinary sewage.

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23692. And afterwards?—It is passed through the tanks, treated with lime in the usual way, and then the effluent goes into the river.

26933. Is that the only treatment?—That is the only treatment.

23694. Merely lime treatment and then discharge directly into the river?—Yes.

23695. Is that to be the treatment of the future?—No.

23696. What are you going to do?—Taking the sewage at 12,000,000 gallons, we are providing for six volumes, three of which will receive the full treatment, and provision is made for the remainder on storm beds. The scheme is now before the Local Government Board.

23697. It has not been decided?—No, the inquiry was held in December, but we have not got the result yet.

[NOTE.—Since this evidence was given the Local Government Board have intimated their willingness to accept the scheme subject to certain conditions, which do not, however, involve any alteration in the system of treatment.]

23698. Would the tank area that you have proposed, and the area of filter beds, be sufficient to treat the which of the storm sewage?—We are providing 16 acres of storm filters in addition to the ordinary filter beds.

23699. Besides?—Yes.

23700. You say in answer to Question 23507: "If storm beds are not kept fed, they will be useless from a bacteriological point of view when storm water is passed over them." Is there any difficulty in feeding storm beds from time to time from the regular tank?—No, and by the arrangement I have adopted, we shall be able to pass sewage over the storm beds regularly.

23701. And keep them in proper order from a bacterial point of view?—Yes, but it would be necessary to distribute the dry weather flow over both contact beds and storm beds. We have to provide sufficient of the former for three times the dry weather flow—about 32,000,000 gallons altogether. Unless such a distribution was arranged, supposing we had on a particular day a flow of 30,000,000 gallons it would simply go through the first contact beds, but if we got to 31,000,000 gallons the remaining 1,000,000 gallons would go over the storm filters. In a dry season it might be months before anything went over the storm beds at all, unless such an arrangement was made as that I have indicated.

23702. Quite so, and you have got to keep those beds in working order practically?—Yes.

23703. There would be no difficulty in doing that?—No. The plans are here if the Commission would like to see them.

23704. Is there any provision made in the Sheffield scheme for detritus tanks to intercept the grit?—Yes.

23705. When you say that provision is made for passing the whole of the six volumes through the continuous settlement tanks, you mean detritus tanks in addition to the continuous settlement tanks?—Yes.

23706. In answer to Question 23530 you say: "When possible the sewage remains in the precipitation tank for about 45 minutes;" is that right?—Yes.

23707. Forty-five minutes?—Yes, of course the flow varies during the 24 hours.

23708. When the quantity to be dealt with is above the normal, this period has to be reduced?—Yes.

23709. Can you reduce the period below 45 minutes?—Yes, it is reduced when necessary.

23710. Then what is the minimum period?—That depends on the rate of flow. During very heavy rain, it would only be about ten minutes.

23711. Would there be any settlement at all in ten minutes?—The sewage would be very dilute.

23712. (*Sir William Ramsay.*) Is there any settlement in 45 minutes?—Oh, yes.

23713. Considerable?—Yes; the tanks have to be sludged twice a day; they are in parallel, and there are 30 of them, each holding 50,000 gallons.

23714. (*Colonel Harding.*) In the sheme that you are proposing to carry out, Mr. Wike, I take it the scheme has been approved by the Local Government Board and is being carried out, is it?—Not the present scheme. The old scheme of course was approved by the Local Government Board, but the present scheme was the subject of an inquiry held only in December last, and we are waiting for the Board's decision.

13715. At the present moment your scheme has not yet been approved?—No.

23716. The Rivers Board I think are pressing the Local Government Board to give their decision?—Yes.

23717. Then that is your final intention?—Yes.

23718. Your last intention; you may have to modify it?—We may have to modify or enlarge it as the Local Government Board suggest.

23719. In your scheme you are proposing to have flowing settlement, without chemicals?—Yes.

23720. Now the answers that you gave just now to General Carey did not seem to me quite to explain what was going to be done. What is the total capacity of tanks that you are proposing to put in?—Sixteen tanks having a total capacity of 15,000,000 gallons.

23721. The total capacity of the tanks will be equal to about a day's dry weather flow?—Yes, including the present fresh water dilution.

23722. Then what was it that you said about 45 minutes' settlement?—That referred to the present quiescent tanks for lime precipitation.

23723. You were not alluding to what was going to be done under your new scheme?—No, I was describing the present state of affairs.

23724. Under your present scheme it would be a 24 hours' settlement?—Yes, under the scheme submitted to the Local Government Board.

23725. And under normal conditions?—Yes.

23726. And in fact the Corporation of Sheffield propose at the same time to deal with a number of storm dilutions?—Yes, we are providing 16 acres of storm beds.

23727. You propose probably to pass some of these dilutions through these settlement tanks?—They will all pass through the settlement tanks.

23728. So there will be times when the speed of flow will be much greater than the 24 hours' rate; it may in fact be a four hours' rate if you pass six volumes?—Yes.

23729. Are we to take it that you propose to deal with six dilutions all through the settlement tanks?—Yes.

23730. And you consider that at times of storm a four hours' settlement, unassisted by chemicals, will be sufficient?—I think it will. Ours is a weak sewage—at least a moderate sewage.

23731. I will ask Mr. Haworth this. If you have a 24 hours' settlement, and there is of course a slow rate suitable for a septic tank, will you not bring about septic conditions before the tank gets sufficiently full of suspended matter to warrant its being emptied?—(*Mr. Haworth.*) I should not propose to use the whole of the tanks in dry weather, but to increase the number as the flow increases.

23732. Then a large proportion of this tank capacity would be reserve capacity for use in time of storm?—Yes; I should propose to use a sufficient number of tanks in order to get the solids down as low as possible—probably 8 or 10 parts per 100,000.

23733. That leads me to ask you what rate of continuous flow, unassisted by chemicals, you propose to have normally for your dry weather flow?—Twice the capacity of the tank.

23734. About twelve hours?—Yes, and to have the tanks sludged, say, once a week.

23735. And what result do you expect to obtain in suspended matter in the effluent?—Well, an average of, say, 8 to 10 parts per 100,000.

23736. Now in coming to a decision of that kind, you have been guided by actual experiment no doubt?—Yes.

23737. And you have found that using the tanks not as septic tanks but simply as settlement tanks, the difference being that you empty them frequently instead of allowing

the sludge to accumulate, you can really reduce to 8 or 10 parts ?—Yes. If you refer to the suspended solids figures which are given at the end of the monthly returns you will find that in the early stages of the septic tank work the solids were down to about 8 parts per 100,000, or below, and of course that septic tank in its earlier stages would be in exactly the same condition as the flowing settlement tanks.

23738. Tell me just why you propose to empty the sludge from these tanks every week so as to prevent the septic action; is it because you think leaving the sludge in the tank and permitting septic action to be developed that you would get a large quantity of suspended matter in the effluent, or for what other reason ?—That is one reason; we should have the sludge produced in small quantities regularly, and an accumulation of sludge will not occur; there is less liability of having a large amount of suspended solids carried out. We have found in our septic tank that after a few months work the septic condition is complete, and that large masses of sludge rise in the tank and pass out with the effluent, the suspended solids at times being very high indeed; we wish to avoid that.

23739. Are you able to tell us what would be about the amount of suspended matter coming out in the effluent if the tanks were used as septic tanks at the same rate of flow ?—By increasing the flow from a septic tank ?

23740. No; you are proposing to flow it at a 12-hours' rate ?—Yes.

23741. And you expect to reduce the suspended matter down to 8 or 10 parts per 100,000 ?—Yes.

23742. And you propose in doing that to remove accumulations weekly ?—Yes.

23743. Well, if you do not remove the accumulations weekly, and work the tank just in the same way, the same 12 hours' rate, leaving the accumulations in, what increase of suspended matter would you expect to get from what would then become a septic tank ?—I should expect to get a very considerable increase, because in the case of the septic tank itself, at the 24 hours' rate we find that after a few months the suspended solids figure increases very considerably.

23744. I see; accumulations arise ?—Yes.

23745. Have you tried any actual experiments at the 12 hours' rate with the septic tank ?—Not with the septic tank, but we find with the 24 hours' rate the quantity of suspended solids increases; therefore one might fairly assume that with the 12 hours' rate the quantity would be still larger.

23746. Supposing you were using your tank as a septic tank, but you went on the plan of removing weekly some portion of the accumulated sludge, so as to maintain a constant tank capacity, would you or would you not, do you think, obtain similar results to what you expect to obtain from this non-septic settlement ?—I think you would possibly obtain a satisfactory result in that way.

23747. Would the septic conditions of the tank bring about some digestion of the suspended matter deposited in it ?—To some extent.

23748. To the extent that you have told us of—one-third ?—Yes.

23749. Well, is not that a proportion worth considering ?—Well, there are several points to consider in that matter. If you allow that digestion to go on in the tank, it means that your tank liquor is at times somewhat more difficult to treat in contact beds than it otherwise would be.

23750. I am asking these questions with the idea of bringing out what your reason is for deciding upon an unassisted flowing settlement instead of septic settlement ?—Yes.

23751. The capacity of your tanks being sufficient for either plan ?—Yes.

23752. And I think I gather now that the real reason is that you think the septic effluent would not be so easy to deal with on filters ?—We have found that we can get a result rather better by our settlement than we have from the septic tank.

23753. Well, let us investigate that please. What is the nature of the parallel experiments that you have made ?—We have treated septic tank liquor on clinker contact beds, and given the double contact; and we have treated the settled sewage on clinker contact beds.

23754. Identical contact beds ?—Well, not exactly; the material is similar, but the grading of the material on the surface of the contact bed in the latter case was rather finer than in the other case.

23755. Was the rate of flow exactly the same; was the number of fillings exactly the same ?—The number of fillings of the bed was the same.

23756. And the only difference between the two was the question of the grading of the material?—That is all.

23757. Well, what was the difference in the results obtained ?—The difference was very slight, but it was in favour of the non-septic treatment.

23758. Would you consider yourself warranted in saying that the results would have been better if the conditions had been quite parallel ?—I think so. You mean the results of purification; merely from a purification point of view ?

23759. Yes ?—Well, I do not think there would have been much difference. I think the results are so close that one could hardly say that one system would be better than the other, but there are other objections to the septic tank treatment perhaps more important from a practical point of view.

23760. Will you tell us what they are ?—One of the chief reasons is the question of nuisance. The smell that we get from the septic tank, although it is only a small one, is such as to be a great nuisance to the men working near.

23761. Are you able to suggest to us why in your case at Sheffield there should be this considerable nuisance from a small septic tank, when in other places where in their sewage they have a good deal of iron salts they do not find that result ?—I think there are other places where a similar result is found.

23762. Have you found for instance at Manchester or Leeds there is much nuisance ?—No, I have not; I have noted at other places that there is a great deal of smell from the discharge from the septic tank, and complaints have been made in the newspapers.

23763. Well, in your particular case at Sheffield there is an evident nuisance ?—There is; I think Mr. Wike will confirm me in that. (*Mr. Wike.*) Yes, very strong.

23764. Are we to take it that that is your main reason for not permitting septic conditions to arise in the settlement tanks ?—(*Mr. Haworth.*) That is one reason; another reason is the difficulty of dealing with storm water in tanks. We do not consider that we should be wise in putting a large volume of storm water into tanks in a septic condition.

23765. You are afraid it would wash out some of the accumulated matter ?—Yes, and I think the change from a septic liquor to fresh sewage on the contact beds would be rather detrimental.

23766–7. You are not obliged to pass your storm waters through the septic tanks; you are, in fact, proposing to have a number of tanks as reserve tanks ?—Yes, that is so; we are not obliged to do so, but we thought it better to make such an arrangement.

23768. Now I would like to ask Mr. Wike one or two questions on the important matter of storm waters. In the scheme which Sheffield has at the present time laid before the Local Government Board, to what extent is it proposed to deal with storm waters ?—(*Mr. Wike.*) After three volumes the remainder will pass through the sixteen acres of storm beds.

23769. The remainder to what extent ?—Six times the dry weather flow.

23770. Of the six ?—Yes.

23771. Then Sheffield proposes to deal with three volumes completely ?—Yes.

23772. And to deal with three more volumes over some special beds ?—Yes.

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23773. Actually Sheffield is not treating at all any storm waters ?—All the water that we can take is treated in the works.

23774. What do you mean by " that we can take " ? —That is up to 22,000,000 gallons a day.

23775. Do you mean that the sewer can bring ?—I mean that the works can take.

23776. Can the sewer bring 22,000,000 gallons a day ? —Yes.

23777. That is about, roughly, 50 per cent. of the dry weather flow ?—Yes, 50 per cent. in excess of the dry weather flow.

23778. The dry weather flow being 15,000,000 gallons ? —That includes 3,500,000 gallons of practically pure water.

23779. Well, but nevertheless that is the proportion to the dry weather flow ?—Yes.

23780. Your 3,500,000 gallons of practically pure water does not really affect the question seriously, because even with that amount of dilution, your sewage in its analysis is not dissimilar from the sewage of Manchester or Leeds ? —That I cannot say.

23781. You are under the impression, perhaps, that it is exceptionally weak ?—I thought it was weaker than Leeds or Manchester.

23782. I do not think the difference is very great, but you do not suggest, do you, that you are actually treating at present 22,000,000 gallons a day ?—Oh, no, I mean if there was a heavy rainfall and 22,000,000 gallons came down the sewer, 22,000,000 gallons would pass through the works ; if there were 23,000,000 gallons, 1,000,000 gallons would go over the overflow.

23783. Then you do suggest if 22,000,000 gallons come you pass them at present through your lime precipitation treatment ?—Yes, we do.

23784. Why do not 22,000,000 gallons come frequently to the works ?—Because that volume does not come without there is heavy rain.

23785. But if there is rain sufficient to produce that quantity, it comes to you ?—Yes.

23786. Because I notice that the amount you deal with in the year does not represent anything like 50 per cent. increase on the dry weather flow ; it only represents about 20 per cent. increase, as shown by your answer to Question 23497?—An average of about 17,000,000 gallons is the treated flow.

23787. There is an interesting question which you, as an engineer, may possibly give us your opinion about, and that is : Suppose you did deal with six volumes of your dry weather flow, what might that represent in proportion to the dry weather flow itself. For instance, suppose the dry weather flow during the year were represented by the figure 100, what would the dry weather flow plus five dilutions represent for the year ; how much would it add, do you think—50 per cent., 30 per cent, or how much?—I could not name a figure now. An investigation of the working of the storm overflows would be necessary.

23788. Is it a matter that you have given any attention to ?—No, I am not prepared to give an answer.

23789. But the addition of five dilutions to the dry weather flow might represent 50 per cent. increase over the year of the dry weather flow ?—I should think probably it would, but I should not be prepared to give that as a definite answer.

23790. Now as to this treatment of storm waters, you propose in your new scheme that the whole five dilutions, or six volumes, should pass through these settlement tanks ?—Yes.

23791. And you propose to hold some of them in reserve, so that they would all be used in times of greater flow. I think you said in answer to someone else's question that that dilution at storm times would probably not increase the suspended matter coming away in that effluent, notwithstanding the increased rate of flow ?— I am afraid I do not follow your question.

23792. In times when you are passing a greater flow through the tanks, one would naturally expect that more suspended matter would come out, there being less efficient settlement ?—Yes.

23793. I think I gathered from one of your answers that you thought that storm waters being more dilute would not bring down so much suspended matter ?— The storm waters at first will bring a great deal of suspended matter down. I have a curve here, and there is an analysis made by the chemist showing the variation of suspended matter during storm time.

23794. Then during the time that the extra suspended matter is coming down, you would not get results so good as the usual from this process of settlement ?—No.

23795. You would get a good deal more suspended matter coming away ?—You would get a great deal more suspended matter coming away.

23796. Do you foresee that it would be necessary to have anything else besides this sedimentation ; do you foresee that it would be necessary, to get fairly efficient results, to have a process of filtration, for instance, for the storm waters ?—I think that the passing through the tanks alone would be sufficient.

23797. Even for the first dilution ?—(*Mr. Haworth.*) Storm solids settle rapidly. (*Mr. Wike.*) A great quantity of the grit and mineral matter would be taken out in the catch pits.

23798. Do you think that sedimentation alone would bring about sufficiently good results to permit of the effluent going direct into the stream without filtration ? —Yes, I think so.

23799. Do you think that in regard to the first dilution, say, the first two ?—Well, sir, I think the first dilution contains a great deal of mineral matter, but settlement would take place in the catch pits before it got to the continuous flow tank.

23800. Do you really think that it would settle them sufficiently ?—Yes.

23801. But you are in fact proposing that the first two dilutions, the first three volumes of your sewage, should have some arrangement of storm filters ?—We understand the Local Government Board require us to provide for six times the dry weather flow—three volumes by the complete process and a further three volumes on the storm beds.

23802. You are proposing to do this in deference to the view of the Local Government Board but not acting on your own opinion ?—To comply with what we think is their requirement.

23803. And what you are proposing to do is to pass over the storm beds an effluent which had been previously settled ?—Yes.

23804. And you keep your storm beds in condition by filling possibly once a day ?—(*Mr. Haworth.*) The storm beds are all arranged so that they may be used as first contact beds. (*Mr. Wike.*) Quite so, all of them. (*Mr. Haworth.*) What we are afraid of is that the Local Government Board will insist on a fixed weir so that we cannot discharge to the storm beds until two dilutions occur, so that we should have to take two dilutions with our regular plant before any sewage could pass to the storm beds. The regulation as I understand it is that we may treat two dilutions by our regular plant before we can allow any storm water to pass to the storm beds.

23805. (*The Secretary.*) I think the Local Government Board have actually enforced that ?—There are cases where the weir is fixed so that it would not come into operation until two dilutions are flowing.

23806. (*Colonel Harding.*) But you would prefer to treat these dilutions over other contact beds, not the same contact beds ?—I should prefer to have the whole area, both storm bed and contact bed area, available for treating the flow as it came and gradually increase the load over the whole area rather than load the ordinary plant with it and merely put the excess on to a comparatively large area of storm beds.

23807. And do you say that the Local Government Board will not permit you to do that ?—Their decision has not been given yet. (*Mr. Wike.*) That is what I understood was their requirement, and that is what we are providing.

23808. Are we to understand that you are under the impression that the Local Government Board propose that you shall not use the special storm water beds until the flow exceeds three volumes over your normal plant? —Yes.

23809. (*Sir William Ramsay.*) May I ask would that interfere with keeping your storm beds in order?—(*Mr. Haworth.*) That is the difficulty; I do not see how the storm beds could be kept in order by such an arrangement.

23810. (*Major General Carey.*) That is the very point I asked in my examination of Mr. Wike, whether your storm beds could not be kept in order by diverting part of the sewage on to them instead of your ordinary tanks? —(*Mr. Wike.*) I thought I said they could.

23811. That is how I understood you?—Yes, that provision is made in this scheme for diverting sewage, if found necessary, over the storm beds.

23812. (*Sir William Ramsay.*) But you are afraid that that provision would be nullified by the Local Government Board?—It is only fair to say the scheme is before the Local Government Board, and we have not heard from them since the inquiry last December.

23813. (*Colonel Harding.*) What causes you to think that they take that view?—I gather that from interviews I have had from time to time

23814. Do you know any place where they have insisted on that course being followed.—(*Mr. Haworth.*) There are some works where weirs are fixed in order to prevent storm water passing to the storm filter before two dilutions have been obtained. (*Mr. Wike.*) The scheme which has been submitted does not show that. It shows that the storm water can be diverted either to the first contact beds or to the storm filter beds. (*Mr. Haworth.*) The question was raised at the inquiry. We have a penstock in our main channel, in the scheme, which could be lifted so as to allow us at any time to pass sewage to the storm filters, and the question was raised by one of the inspectors as to whether that should not be fixed.

23815. Does that weir come in after the settlement tanks?—Yes, it comes in between the ordinary contact beds and the storm beds. A sluice is arranged.

23816. Now would you perhaps let me put it in this way—how far were you proposing to deal with the increased flow upon your contact beds?—To three times the dry weather flow.

23817. Yes, but I gather that you do not think it desirable?—No.

23818. How far do you think it is desirable for you to treat an increased flow upon your contact beds?—Beyond the dry weather flow?

23819. Beyond the dry weather flow?—My point was this: I think it would be better to increase the load over the whole area.

23820. Over the whole area? Yes, I know, but quite apart from that how far do you think it is desirable that you should increase the flow over your contact beds? —Our scheme provides sufficient contact beds to give three fillings a day with two dilutions.

23821. So that under normal conditions you would only get one filling a day?—That is so.

23822. And one filling a day would no doubt give you very fair result?—A very good result indeed.

23823. Is there any reason why you should not increase it to three fillings a day?—None whatever, but the point is this: we might give one filling a day for our ordinary plant but at the same time we should have the area of the storm beds receiving nothing and I think it would be better to give even less than one filling a day over the whole area and so keep all the beds in active condition.

23824. Do you think that objection would be made to your using the whole area and therefore obtaining better results for the dry weather flow?—Well, we understood that that was the Local Government Board's attitude.

23825. It is a point upon which you will probably have further information later on?—(*Mr. Wike.*) The scheme shows that we intended to avail ourselves of the whole area.

23826. At what rate per cubic yard are you proposing to deal with the effluent?—(*Mr. Haworth.*) We have assumed the capacity of the filter is one-third the actual tank capacity; that is the basis upon which the Local Government Board insist.

23827. That is what you have calculated upon?—Yes, our experience shows that that is too much for first contact beds and perhaps a little low for second contact beds.

23828. Now what does that give you per cubic yard? —One hundred and sixty-eight gallons per cubic yard for three fillings.

23829. For three fillings?—Yes, per day.

23830. That is as a storm bed?—That is the ordinary bed.

23831. In dry weather times you do not propose to use at anything like such a rate?—No, one-third of them.

23833. And is it proposed to have double or only single contact?—Only single contact. (*Mr. Wike.*) Provision is made for double contact if afterwards found necessary.

23834. Do you find from your experience that the analytical results you obtain from single contact with settled effluent of 8 to 10 parts per 100,000 are good enough? —(*Mr. Haworth.*) Well, we find that it approximates very closely to the standards required by the Rivers Board, but we cannot guarantee always to be below that standard. But the effluents are more generally non-putrescible than putrescible, and we think that to begin with, it is a reasonable standard to attain. If afterwards we found, as we think we may, that only a very modified form of second contact may be sufficient to bring the effluents that are not quite satisfactory up to a proper standard, such modified arrangements could then be made.

23835. Then I will ask Mr. Wike, who has to do with the engineering features of the scheme, does your scheme permit of second contact beds if, as is not unlikely, they are found to be necessary?—(*Mr. Wike.*) Yes, they are so arranged that second contact beds could be provided —there is a sufficient area of land available for the purpose.

23836. The levels permit of it and the area of land permits it?—That has been one of the difficulties. The area of land is sufficient, but on account of the beds it would be necessary to pump the effluent from the first contact beds on to the second.

23837. And in the scheme that you have laid before the Board you have shown that the Corporation is willing, if necessary, to do this?—We have shown there is sufficient land.

23838. Well, but you have put before the Local Government Board a scheme for approval, have you not? —Yes.

23839. The scheme that you have put before them is simply one of single contact?—A single contact.

23840. That is all you propose?—Yes, at present.

23841. But Mr. Haworth tells us that it only approximates to what is considered by your supervising authority to be sufficient, and that the results are only occasionally non-prutrescible?—Yes. (*Mr. Haworth.*) They are more generally non-putrescible than putrescible.

23842. May I put it that they are frequently putrescible?—Frequently, yes; but only very slightly.

23843. On the question of road water, Mr. Wike, does road water to a considerable volume come into your sewers?—(*Mr. Wike.*) A great deal of it does. Some goes direct into the river and streams.

23844. Have you got Mr. Haworth to make any analyses of these road waters?—Yes, there is an analysis and a curve.

23845. Tell us without going into the details of the analysis, which no doubt will be put in, is it not very polluting?—(*Mr. Haworth.*) The samples were samples of the first flush of the road water taken from the gulleys.

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23846. What is the result in albuminoid ammonia?—Albuminoid nitrogen (this is a sample from the granite paving). ·469 pts. per 100,000.

23847. That is not very much better than your dry weather flow of sewage?—No; and the oxygen absorbed in four hours 11·9 pts. per 100,000.

23848. That is quite as bad as your ordinary sewage? Is it proposed that those road waters should pass permanently direct to the river?—(*Mr. Wike.*) No, sir, those in the neighbourhood of the shambles or from streets where there is a great deal of traffic near the markets are already connected to the sewers; it would not be right to let those go into the river.

23849. I think it leads one to think that possibly, as regards volume at Sheffield, it would be considerably increased when that is done?—I beg pardon; the liquid represented by the analysis Mr. Haworth has been showing just now does not go into the river. (*Mr. Haworth.*) These waters are all going into the sewers.

23850. Are all going into the sewer?—Yes.

23851. But does not your answer to Question 23513 suggest that all this water passes direct into the river, that gulleys are connected direct to rivers and streams?—(*Mr. Wike.*) That is only in certain parts of the town.

23852. It does not apply to any great extent?—Oh, no, sir; only to a very small quantity. At the foot of some of the steep gradients that I have mentioned, where we have streets one in five to one in ten we, take the water straight into the river, but the bulk of the gulleys in the town are connected direct to the sewers.

23853. Now in regard to the production of sludge, what do you anticipate when your new scheme is in full operation will be the volume of sludge to be produced at the Sheffield works daily?—We make now from 800 to 1,000 tons a week.

23854. That would be considerably increased, would it not, when you get these more efficient works in operation?—I think it would be reduced.

23855. You are not now treating your storm waters?—No, but a great quantity of lime is now used which will be unnecessary when the new scheme is in operation.

23856. At present you have lime settlement?—Yes.

23857. That no doubt would produce a larger quantity of sludge; on the other hand, when you have dispensed with the lime and treat the storm waters the amount may be larger than you are treating now?—We anticipate a smaller quantity.

23858. Well, the farmers will not take it; what do you propose to do with it?—We propose to continue our present method of disposal.

23859. You are doing with it now—what?—We have purchased land some distance from Sheffield; after being partially dried the sludge is taken in special wagons over the railway to this land and tipped upon it. Before tipping is commenced the top soil is taken off, the sludge is then tipped 7 or 8 feet deep; eventually the land is returfed and made into arable land.

23860. How long does it take to dry the sludge under those conditions?—Some years.

23861. Some years?—Yes.

23862. Is the area which you have available a large one?—It is about 20 acres.

23863. Will it last you indefinitely for this disposal of the sludge?—We shall have to take more.

23864. Buy more land?—Yes.

23865. Does that method of drying the sludge not give rise to considerable nuisance?—We have had certain complaints, but the complaints I think are really due to another cause. We are on one side of the railway and there is a local sewage farm on the other the effluent from which passes the boundary of our land, and we think this is what gives occasion for complaint.

23866. You think they are the sinners rather than Sheffield?—Yes. There is a certain amount of smell but nothing objectionable I think; the sludge is heavily limed.

23867. Where you do in fact have these lagoons is a long way from Sheffield?—No, the lagoons themselves where the sludge is dried are at the sewage works about three miles from the centre of the city.

23868. You take it half dried from there?—Yes, with 80 to 85 per cent. moisture.

23869. You take it in that state to some further place; how far is that place away?—Seven or eight miles away.

23870. The observations you made about certain nuisances being complained of, are at that place?—Yes.

23871. You are under the impression that is not town sludge but their effluent that smells?—At certain times of the year there is some smell from the sludge.

23872. There is an important question upon which I should like very much to have your view as an engineer. It occurs to one that what you are proposing to do is a thing that cannot be done for ever more; it is a provisional arrangement pending something else; has it ever occurred to you to burn the sludge; do you think that is a practicable thing?—From my inquiries and experience I am rather afraid it is not

23873. It would require, would it not, in the first instance pressing out the bulk of the water?—Yes, I have seen many works where sludge is pressed, I may be mistaken, but I do not think any of them are satisfactory.

23874. Do you mean that the pressing is not satisfactory?—There is the cost, the difficulty of manipulation, and after going to the expense of pressing the pressed sludge has still to be disposed of.

23875. That was the point I rather wanted your opinion upon, have you any experience to enable you to answer the question; is it practicable to burn sludge cake?—I should not think it could be satisfactorily and economically done.

23876. What leads you to think not?—The information I have been able to obtain from time to time.

23877. You do not express a strong opinion anyway, not having personal experience?—No, it is simply in my mind from having visited from time to time other works in England.

23878. (*Sir William Ramsay.*) May I ask, Mr. Wike, before you pass away from the subject, how much sludge have you to dispose of?—From 800 to 1,000 tons a week.

23879. Then is it not a very expensive matter indeed to partially dry that and take it away to this other place?—No; the result of my calculations was to show that we could take it away cheaper than we could press it. Our railway rate is only 6d. per ton.

23880. And will there be no difficulty ultimately in getting land to put it on to because, at the rate of 1,000 tons a week, you fill up a very large space in a very short time?—No; this sludge keeps consolidating; I think we have been tipping twelve years.

23881. (*Colonel Harding.*) Then just a word about these contact beds, Mr. Wike. You foresee, sooner or later, that the capacity of the contact beds will be reduced so as to compel you to do something; either to replace the material or to wash it?—Yes.

23882. You propose to put on the contact beds an effluent containing eight to ten parts per 100,000 suspended matter?—Yes.

23883. What length of experience have you had in the treatment upon the contact beds of such an effluent?—About four or five years, but our oldest contact beds have been in use seven years.

23884. What point have you reached with the beds which have been working five years in regard to the reduction of capacity?—I have diagrams and tables which I will put in showing this.

23885. Can you tell me the point to which the capacity has been reduced at the end of five years?—In the first contact beds to about 21·3 per cent.

23886. Of the empty tank capacity?—Yes.

23887. What was the original water capacity?—The original water capacity was 56·7 per cent. That was on July 23rd, 1900. At the end of September, it was 41 per cent.

23888. What is it now?—It is about 21·3 per cent.

23889. There has been a fall of considerably more than half?—Yes.

28890. How far do you consider, looking upon this matter as an engineer, that it is practicable to reduce

the capacity? What is the economical point when it is cheaper to stop and wash the material than to go on putting a constantly reduced volume upon the bed?—I should think at about the point we have reached.

23891. Then may I take it from your experience that you do under the conditions proposed, at the end of five years reach the point when it is necessary to wash the material or to renew?—That depends a great deal on the sewage.

23892. I mean under the conditions that you are proposing to carry out and upon which you have carried out serious experiments?—I think the conditions will improve. We have at the present time 285 miles of macadamised roads, from which we get a good deal of grit. This grit washes down to the works and some deposits in the contact beds. We are gradually converting these roads into paved roads.

23893. May I take it that your view is, that the point when washing becomes necessary has, in fact, been reached in five years, but you hope by diverting certain matters which are now washed off the roads to increase the period?—Yes.

23894. Do you expect to increase it much?—Possibly by 30 or 40 per cent.

23894*. As a matter of fact you reach that position in five years now?—No; I should not like to fix that point (*Mr. Haworth.*) The capacity of that particular bed is the same now as it was two years ago. (*Mr. Wike.*) I was going to explain that it has been at that capacity for about three years.

23895. Then would your answer to my question be that you have, at the end of five years, reached what you consider to be the economical limit, but that you do not anticipate any further reduction and you anticipate that you would be able to continue at that limit for some time?—If the bed is turned over, we may be able to go on for a year or two.

23896. If the bed is turned over?—Yes.

23897. Would you prefer that to washing?—No.

23897*. It is rather expensive also to turn it over?—Probably it would be more expensive than washing.

23898. More expensive?—Well, I think it would be to turn the whole of the bed over.

23899. Then why do you not prefer washing?—I do prefer washing.

23900. Let us make sure that we quite understand what we mean by washing. You do not suggest that it is possible to wash out a contact bed by streaming at a high rate through it?—That is what I thought might be possible.

23901. I only thought that might be in your mind because in answer to Sir William Ramsay you spoke about putting a passing flow under pressure?—Yes.

23902. Well, we should be interested in knowing how far your experiments have led you to think that it is practicable to force a flow through a contact bed so as to wash it?—I have not yet tried washing on a large scale.

23903. It is merely an impression that it may be possible but experience may show that it is not possible?—I think in time satisfactory means may be devised.

23904. As to the alternative of washing, taking it out and eliminating the dirty matter and putting the clean material back again, is that practicable from the point of view of expense?—I am afraid not. We get our best results from graded tanks, and to take out, wash, and re-grade the old material would probably be more expensive than to buy new.

23905. Do you think that after washing it would not be possible to eliminate the degraded material, the broken down material?—Yes.

23906. You do not think it would be possible?—I do not think it would be practicable to take it out of the whole tank and wash it in that way.

23907. Just explain to us what kind of washing you propose. Here is a bed, which after a certain length of time has reached a condition when it is no longer profitable to go on passing the effluent over it?—Yes.

23908. What is to be done? Is the bed to be emptied and new material put in; is the material to be washed or what is to be done and how do you propose to do it?—At the present time we should do as we have done, take the whole of the material out. In one of the large beds, which I described to you, at first the material was coke; it became clogged, the whole of it was taken out but could not be washed as it was disintegrated. The clinker we can take out, and as it keeps strong and does not crumble we can wash it. My idea was that some method might be devised of forcing water under pressure to the beds and so wash the material as it lay in position in the bed.

23909. If that should prove not to be possible—I am afraid very likely it will be found to be impossible—what other method do you propose to follow?—The only other thing would be to take the material out of the beds.

23910. And wash it, or screen it, and put it back again?—Yes.

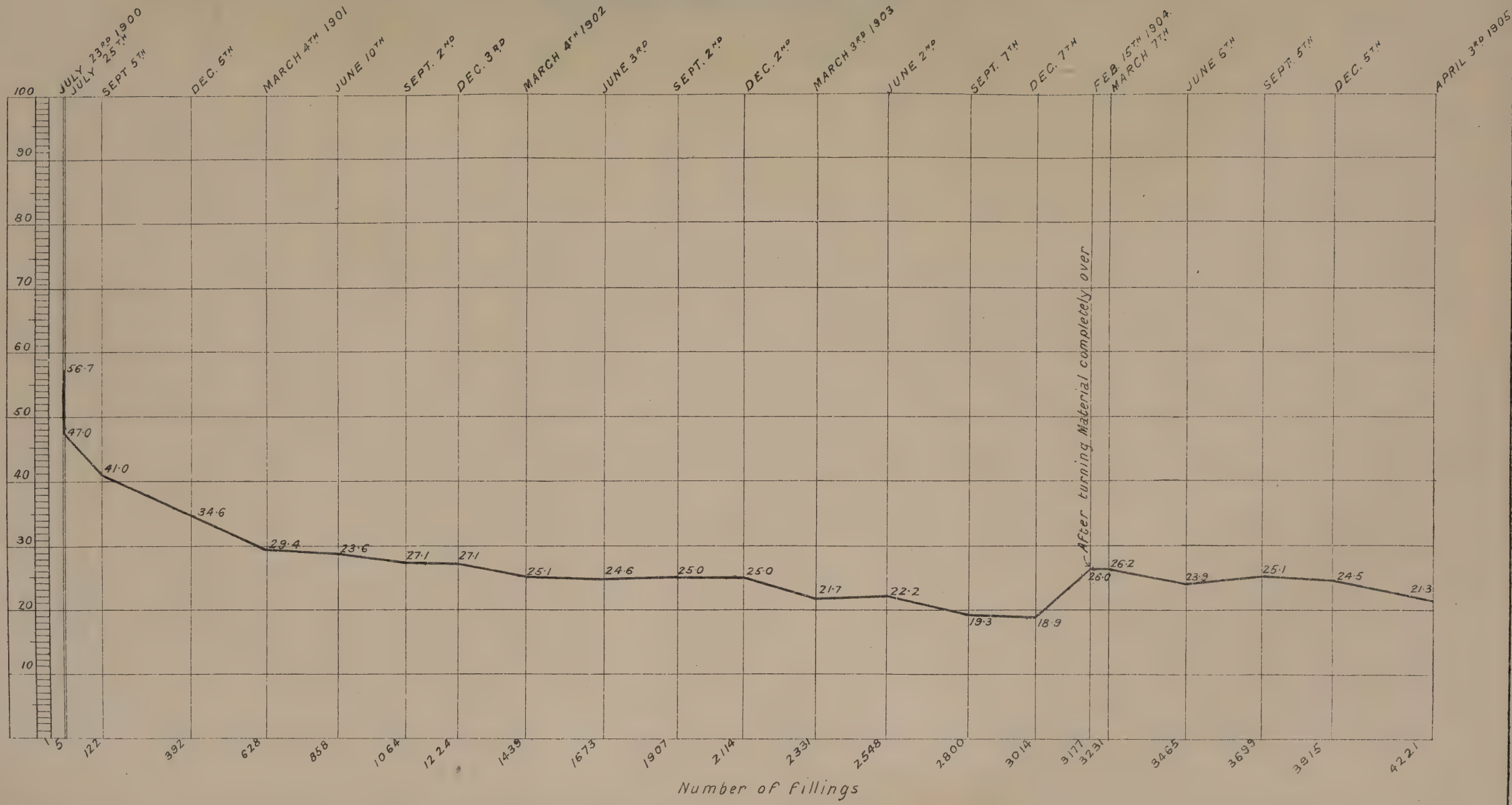
23911. Is that practicable from the point of view of cost?—At present with the primitive arrangements we have it would be a very costly thing, but I think on a large scale (and one would get thirty or forty acres of this stuff to wash in time) a process might be arranged that would not be so costly.

23912. The problem is obviously one which is present to your mind, is it not?—It is and it has been for some time.

23913. And you evidently consider it would be ptacticable from the point of view of cost or you would not propose to put contact beds?—No. We are proposing to provide contact beds.

23914. You think it is practicable?—I think it is practicable, and in time, when more experience has been gained, the cost may be reduced. One thing I would like to make clear, and that is with respect to the time of settlement in the quiescent tanks. I was alluding to those in use at the present time, the lime precipitation tanks, which were constructed eighteen years ago. These are now supposed not to give efficient treatment to the sewage and for that reason we are asked by the Local Government Board and the West Riding Rivers Board to remodel our works. The Corporation have submitted to the Local Government Board a scheme including settlement tanks to hold 15,000,000 gallons, sixty first contact beds, with an area of thirty acres, and sixteen acres of storm filters, the estimate being £270,000. The Board now have this under consideration, and should they require second contact beds as well, pumping will be necessary and the cost will be increased to about £400,000. The land acquired is sufficient for the second contact beds should they have to be constructed.

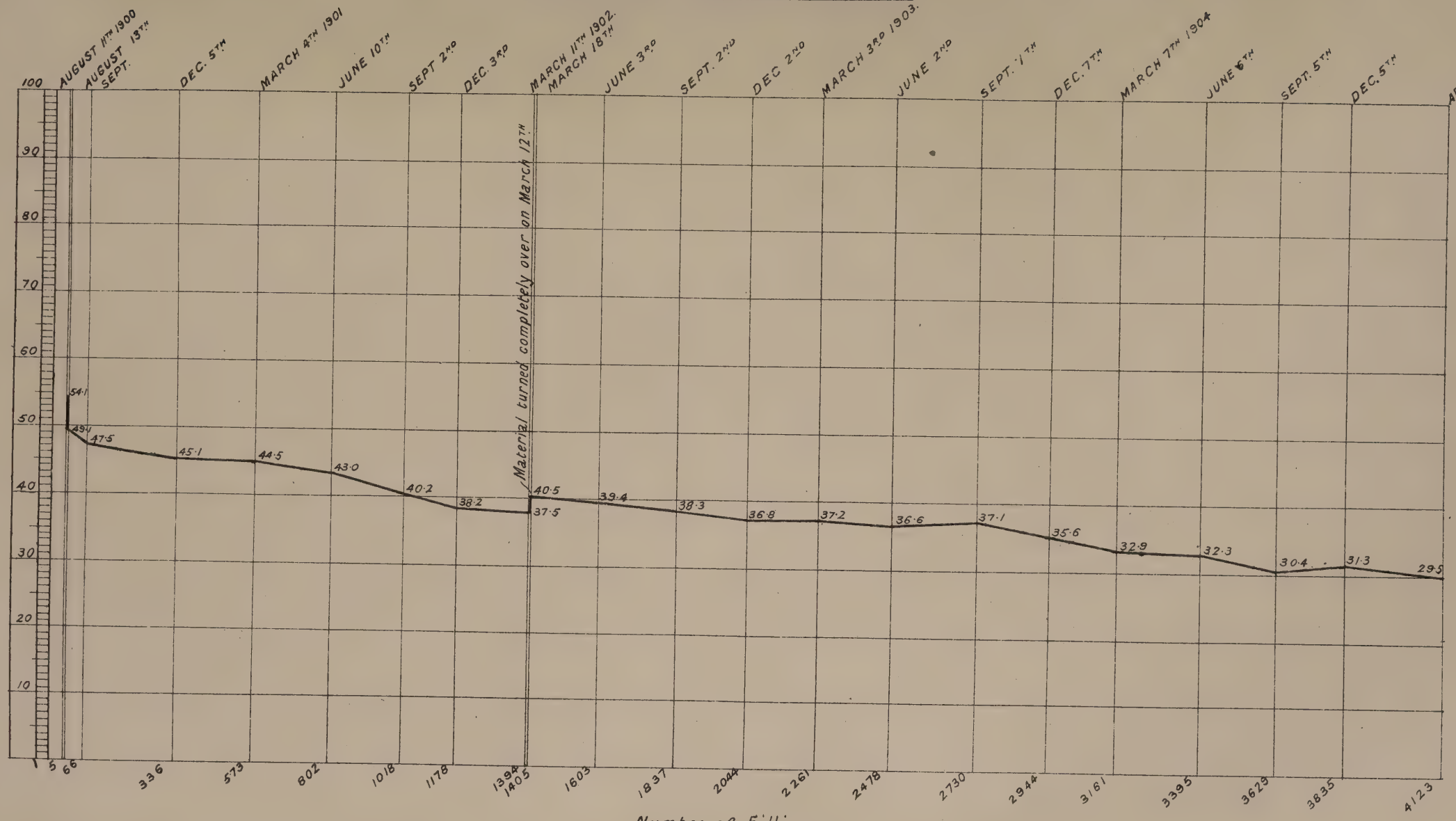
Diagram shewing Variations in Capacity of Experimental 1st Contact Bed at the Sheffield Sewage Works.



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DIAGRAM SHEWING VARIATIONS IN CAPACITY OF EXPERIMENTAL 2ND CONTACT BED AT SHEFFIELD SEWAGE WORKS.



3236.

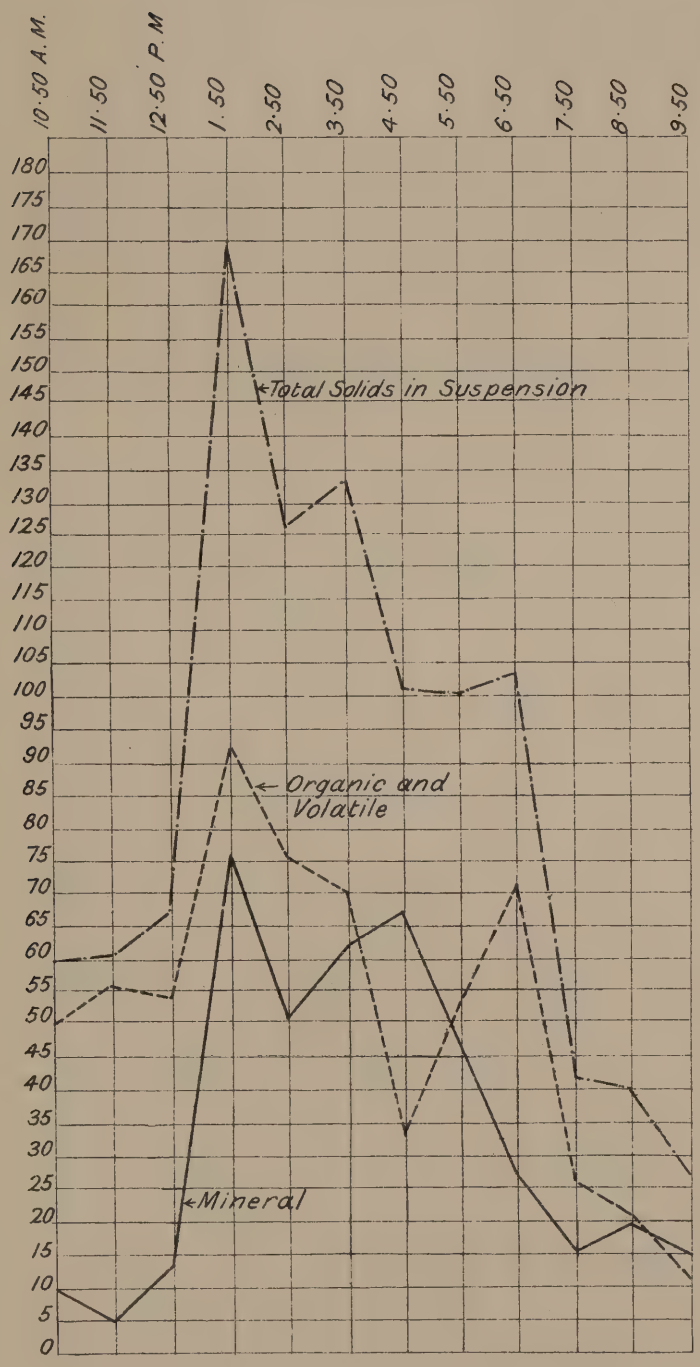
Weller & Graham, Ltd. Litho. London.

Royal Commission on Sewage Disposal.

SUSPENDED SOLIDS DURING STORM AT SHEFFIELD.

13TH FEBY 1905.

Rainfall ..... ·11



Vertical Figures represent parts 100,000.

Weller & Graham, Ltd · Litho, London.

SHEFFIELD.

Appendix to Evidence of Mr. C. F. Wike and Mr. John Haworth.

Tables showing average analyses of sewage, tank liquor, and filter effluents at Sheffield.

PROCESSES OF TREATMENT:

(*a*) Double Contact Beds treating Crude Sewage.

(*b*) Septic Tanks and Double Contact Beds.

(*c*) Sedimentation Tanks and Double Contact Beds.

SHEFFIELD.

May, 1903.

SEWAGE:—

Average daily flow	18,870,000 gallons	Total rainfall	3·90 inches.
Maximum daily flow	22,690,000 „	Rainfall	·04 „
Minimum daily flow	12,130,000 „	Rainfall	—

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·47	3·78	1·92
Albuminoid nitogen	·28	1·01	·60
Oxygen absorbed from $KMnO_4$ in 4 hours	2·61	10·43	5·80
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 12.

SEPTIC TANK.—

Average flow through the tank - - - - 57,000 gallons.
Amount of sludge dealt with during month - - nil.
N.B.—Tank was cleaned on April 3rd, 1903.

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·58	3·76	2·1
Albuminoid nitrogen	·14	·43	·31
Oxygen absorbed from $KMnO_4$ in 4 hours	1·88	4·31	2·87
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 7.

SETTLED SEWAGE.

Average settlement given - - - - - 2 to 3 hours.
Amount of sludge dealt with during month - - 61 tons (95% water).

Average Analysis of Settled Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·70	2·58	1·60
Albuminoid nitrogen	·10	·32	·22
Oxygen absorbed from $KMnO_4$ in 4 hours	2·03	4·90	3·26
Suspended solids	—	—	—
Soluble solids	—	—	

Number of samples analysed for the average = 5.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - - - -
Number of times secondary beds were filled during month - - - - - - - - -
Amount of sewage treated per cube yard per 24 hours - - - - - - - - -

Details of working of a newly-made contact bed are given in later months. The old beds, owing to filling up with detritus, could not be accurately gauged.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - -	—	—	—
Nitric nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	—	—	—
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average =

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 81.
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - - 1st contact, 108 gallons ; 2nd contact, 183 gallons.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	·06	·54	·25
Albuminoid nitrogen - - - - - - - -	·03	·10	·06
Nitric nitrogen - - - - - - - - -	2·43	·81	1·50
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	·34	1·10	·65
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 7.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - - - - 78.
Amount of liquid treated per cube yard per 24 hours - - - - - - 123 gallons.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	·058	·35	·15
Albuminoid nitrogen - - - - - - - -	·017	·11	·05
Nitric nitrogen - - - - - - - - -	1·99	1·01	1·55
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	·41	1·24	·64
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 5.

REMARKS.—The beds treating *crude* sewage are contained in earth walls ; the gaugings are therefore approximate only.

SHEFFIELD—*continued.*

June, 1903.

SEWAGE:—

Average daily flow	16,195,000 gallons	Total rainfall	1·42 inches
Maximum daily flow	19,070,000 „	Rainfall	·06 „
Minimum daily flow	12,020,000 „	Rainfall	—

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	2·82	5·29	3·58
Albuminoid nitrogen	·56	1·13	·83
Oxygen absorbed from $KMnO_4$ in 4 hours	4·30	10·07	6·88
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

SEPTIC TANK.—

Average flow through the tank - - - - - - - - - - 57,000 gallons.

Amount of sludge dealt with during month - - - - - - - - nil.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	2·60	4·70	3·82
Albuminoid nitrogen	·40	·43	·42
Oxygen absorbed from $KMnO_4$ in 4 hours	4·95	5·25	5·14
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 4.

SETTLED SEWAGE.—

Average settlement given - - - - - 2 to 3 hours.

Amount of sludge dealt with during month - - $52\frac{3}{4}$ tons (97% water) (exclusive of detritus removed in catch pits).

Average Analysis of Settled Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	2·94	3·53	3·34
Albuminoid nitrogen	·30	·84	·47
Oxygen absorbed from $KMnO_4$ in 4 hours	3·24	5·25	4·61
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 4.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - 33.
Number of times secondary beds were filled during month - - - - —
Amount of sewage treated per cube yard per 24 hours - - - - —

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average =

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 75.
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - - 1st contact, 107 gallons ; 2nd contact, 186 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·41	1·47	·70
Albuminoid nitrogen	·07	·17	·12
Nitric nitrogen	1·53	·87	1·24
Oxygen absorbed from $KMnO_4$ in 4 hours	·54	1·17	·88
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - 75.
Amount of liquid treated per cube yard per 24 hours - - - - 126 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·23	·76	·55
Albuminoid nitrogen	·035	·15	·082
Nitric nitrogen	1·01	·62	·92
Oxygen absorbed from $KMnO_4$ in 4 hours	·35	1·05	·64
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

SHEFFIELD—*continued.*

July, 1903.

SEWAGE.—

Average daily flow - -	16,630,000 gallons	Total rainfall - - - -	1·75 inches.
Maximum daily flow - -	20,720,000 „	Rainfall - - - - -	·33 „
Minimum daily flow - -	12,430,000 „	Rainfall - - - - -	—

Average Analysis of Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	·94	4·94	3·27
Albuminoid nitrogen - - - - - - - -	·28	1·36	·81
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	5·95	11·31	7·74
Suspended solids - - - - - - - - -	—	—	—
Soluble solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 16.

SEPTIC TANK.—

Average flow through the tank - - - - - - - -	57,000 gallons per day.
Amount of sludge dealt with during month - - - - -	nil.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	2·47	6·23	3·97
Albuminoid nitrogen - - - - - - - -	·21	·58	·40
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	5·27	6·29	5·78
Suspended solids - - - - - - - - -	—	—	—
Soluble solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 8.

SETTLED SEWAGE.—

Average settlement given - - - - - - - - - -	2 to 3 hours.
Amount of sludge dealt with during month - - - - - -	55 tons (95% water).

Average Analysis of Settled Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	1·76	4·94	3·06
Albuminoid nitrogen - - - - - - - -	·28	·58	·38
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	4·53	5·45	5·03
Suspended solids - - - - - - - - -	—	—	—
Soluble solids - - - - - - - - - -	—	—	—

Number of samples analysed for the average = 8.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - 50 (1st contact).
Number of times secondary beds were filled during month - - - - 69.
Amount of sewage treated per cube yard per 24 hours - - - - - 115 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·057	·58	·34
Albuminoid nitrogen	·017	·06	·027
Nitric nitrogen	1·46	·77	·96
Oxygen absorbed from $KMnO_4$ in 4 hours	·27	·70	·49
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 5.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 1st contact, 84; 2nd contact, 84.
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - 1st contact, 105 gallons; 2nd contact, 185 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·35	·70	·57
Albuminoid nitrogen	·01	·15	·07
Nitric nitrogen	1·77	·68	1·04
Oxygen absorbed from $KMnO_4$ in four hours	·55	1·38	·97
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 8.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - - 84.
Amount of liquid treated per cube yard per 24 hours - - - - - 120·9 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·12	·64	·37
Albuminoid nitrogen	·017	·12	·047
Nitric nitrogen	1·21	·48	·94
Oxygen absorbed from $KMnO_4$ in 4 hours	·57	1·13	·75
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	

Number of samples analysed for the average = 8.

SHEFFIELD.

Results expressed in parts per 100,000

Date 1903.	Nature of Sample.	Dissolved oxygen determinations.				Oxygen absorbed in 3 minutes.	Oxygen absorbed in 4 hours. at 80° F.	Ammoniacal nitrogen.	Albuminoid nitrogen.	Nitric nitrogen.	Chlorine.
		Tap water.	Effluent.	2 Volumes of tap water + 1 vol. of effluent at 80° F. for 6 hours.	2 Volumes of tap water + 1 vol. of effluent at 60° F. for 24 hours.						
July 16th	Effluent from coke beds treating raw sewage	·580	·130	·400	·360	·15	·57	·30	·071	1·47	11·1
„ 21st	„ „	·735	·413	·436	·517	·30	·71	·14	·071	·95	10·4
„ 27th	„ „	·880	·415	·362	·476	·21	·58	·59	·023	1·06	12·7
„ 28th	„	·885	·211	·306	·463	·27	·43	·59	·011	1·06	12·1
Aug. 4th	„	·824	·279	·341	·327	·13	·34	·12	·058	1·40	11·5
„ 11th	„ „	·885	·252	·442	·362	·13	·40	·87	·058	1·29	12·0
„ 20th	„ „	·861	·443	·712	·719	·10	·38	·35	·017	1·44	9·1
„ 24th	„ „	·823	·399	·683	·626	·17	·30	·13	·035	1·88	10·0
Sept. 15th	„ „	·921	·874	·753	·578	·06	·20	·12	·035	2·34	10·8
Oct. 5th	„ „	·801	·345	·507	·494	·23	·51	·29	·036	1·81	11·1
„ 6th	„ „	·968	·398	·508	·551	·14	·27	·17	·071	1·85	9·6
July 27th	Effluent from clinker beds treating settled sewage	·880	·219	·351	·620	·31	·94	·64	·035	·95	12·5
Aug. 4th	„ „	·824	·157	·279	·273	·21	·87	·29	·120	1·87	11·5
„ 17th	„ „	·878	·273	·511	·381	·34	·57	·29	·123	1·34	9·1
„ 24th	„ „	·823	·459	·646	·544	·17	·44	·32	·047	1·44	10·0
Oct. 6th	„ „	·968	·336	·432	·402	·39	·63	·18	·071	1·00	9·7
July 28th	Effluent from clinker beds treating septic tank effluent	·885	·164	·361	·422	·67	1·11	·70	·141	·70	12·0
Aug. 11th	„	·885	·143	·389	·354	·18	·98	·64	·117	·70	12·1
„ 18th	„ „	·892	·232	·470	·279	·30	·68	·12	·105	·64	8·3
„ 20th	„ „	·861	·457	·691	·524	·24	·77	·11	·105	·74	9·4
Sept. 15th	„ „	·921	·618	·349	·464	·48	·70	·47	·082	·71	11·1
Oct. 5th	„ „	·801	·208	·533	·549	·35	1·20	·53	·152	1·52	11·6

SHEFFIELD—*continued.*

August, 1903.

SEWAGE.—

Average daily flow - - 17,040,000 gallons - Total rainfall - - - - 3·27 inches.
Maximum daily flow - - 22,370,000 „ - Rainfall - - - - - ·60 „
Minimum daily flow - - 11,940,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·18	3·17	2·28
Albuminoid nitrogen	·39	·94	·65
Oxygen absorbed from $KMnO_4$ in 4 hours	3·80	6·38	5·40
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=8.

SEPTIC TANK.—

Average flow through the tank - - - 57,000 gallons per day.
Amount of sludge dealt with during month - nil.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·53	3·88	2·47
Albuminoid nitrogen	·28	1·09	·46
Oxygen absorbed from $KMnO_4$ in 4 hours	3·98	5·30	4·65
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=4.

SETTLED SEWAGE.—

Average settlement given - - - - 2 to 3 hours.
Amount of sludge dealt with during month - 60 tons (94% water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·53	2·24	1·96
Albuminoid nitrogen	·35	·82	·55
Oxygen absorbed from $KMnO_4$ in 4 hours	2·84	3·31	3·13
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=4.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - 44
Number of times secondary beds were filled during month - - - - - 73
Amount of sewage treated per cube yard per 24 hours - - - - - 112

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·12	·82	·41
Albuminoid nitrogen	·017	·12	·067
Nitric nitrogen	1·15	·77	·96
Oxygen absorbed from $KMnO_4$ in 4 hours	·11	·90	·39
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=8.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 78
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - 1st contact, 97 gallons ; 2nd contact, 191 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·11	·64	·32
Albuminoid nitrogen	·06	·12	·09
Nitric nitrogen	1·28	·95	1·10
Oxygen absorbed from $KMnO_4$ in 4 hours	·40	·98	·70
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=4.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - 78
Amount of liquid treated per cube yard per 24 hours - - - - 122·4 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·12	·37	·26
Albuminoid nitrogen	·05	·12	·081
Nitric nitrogen	1·53	1·02	1·33
Oxygen absorbed from $KMnO_4$ in 4 hours	·38	·87	·55
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average=4.

SHEFFIELD—*continued.*

September, 1903.

SEWAGE:—

Average daily flow	17,070,000 gallons	Total rainfall	3·10 inches.
Maximum daily flow	22,290,000 „	Rainfall	1·28 „
Minimum daily flow	11,990,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·68	2·94	2·61
Albuminoid nitrogen	·77	1·09	·87
Oxygen absorbed from $KMnO_4$ in 4 hours	6·43	11·44	9·58
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 6.

SEPTIC TANK.—

Average flow through the tank - - - - - - - 57,000 gallons per day.

Amount of sludge dealt with during month - - - - 11 tons (78% water).

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·35	2·94	2.62
Albuminoid nitrogen	·28	·55	·45
Oxygen absorbed from $KMnO_4$ in 4 hours	5·83	6·25	6·04
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 3.

SETTLED SEWAGE.—

Average settlement given - - - - - 2 to 3 hours.

Amount of sludge dealt with during month - - 11,550 gallons (97% of water), 51 tons.

Average Analysis of Settled Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	2·12	2·94	2·50
Albuminoid nitrogen	·28	·53	·41
Oxygen absorbed from $KMnO_4$ in 4 hours	4·25	5·39	4·65
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 3.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - - - 45
Number of times secondary beds were filled during month - - - - - - - - 74
Amount of sewage treated per cube yard per 24 hours - - - - - - - 112

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·11	·55	·28
Albuminoid nitrogen	·03	·11	·05
Nitric nitrogen	2·17	·57	1·28
Oxygen absorbed from $KMnO_4$ in 4 hours	·20	·98	·41
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 6.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 1st contact, 76 gallons; 2nd contact, 76.
Amount of liquid treated per cube yard per 24 hours - 1st contact, 97 gallons; 2nd contact, 189 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·47	·70	·62
Albuminoid nitrogen	·07	·10	·08
Nitric nitrogen	2·34	1·10	1·64
Oxygen absorbed from $KMnO_4$ in 4 hours	·54	1·21	·81
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 3.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - - 76
Amount of liquid treated per cube yard per 24 hours - - - - - - 123·6 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·35	·41	·36
Albuminoid nitrogen	·08	·12	·09
Nitric nitrogen	1·40	·58	·87
Oxygen absorbed from $KMnO_4$ in 4 hours	·65	·97	·81
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 3.

SHEFFIELD—*continued.*

October, 1903.

SEWAGE.—

Average daily flow	20,450,000 gallons	Total rainfall	4·71 inches.
Maximum daily flow	24,370,000 „	Rainfall	·45 „
Minimum daily flow	13,060,000 „	Rainfall	·01 „

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·06	3·29	1·77
Albuminoid nitrogen	·28	·88	·63
Oxygen absorbed from $KMnO_4$ in 4 hours	4·97	9·81	6·55
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

SEPTIC TANK:—

Average flow through the tank	57,000 gallons.
Amount of sludge dealt with during month	nil.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·06	3·27	1·67
Albuminoid nitrogen	·14	·63	·32
Oxygen absorbed from $KMnO_4$ in 4 hours	3·27	5·98	4·25
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

SETTLED SEWAGE.—

Average settlement given	2 to 3 hours.
Amount of sludge dealt with during month	50 tons (97% water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·58	1·88	1·21
Albuminoid nitrogen	·17	·45	·28
Oxygen absorbed from $KMnO_4$ in 4 hours	2·67	5·20	3·70
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - - 32
Number of times secondary beds were filled during month - - - - - - - 76
Amount of sewage treated per cube yard per 24 hours - - - - - - - —

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·06	·30	·09
Albuminoid nitrogen	·012	·07	·024
Nitric nitrogen	2·45	·81	1·44
Oxygen absorbed from $KMnO_4$ in 4 hours	·11	·51	·32
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 8.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 81
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - - - 1st contact, 102 gallons; 2nd contact, 185·1 gallons.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·12	·64	·30
Albuminoid nitrogen	·012	·15	·042
Nitric nitrogen	1·81	·70	1·17
Oxygen absorbed from $KMnO_4$ in 4 hours	·17	1·20	·70
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 8.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - 81
Amount of liquid treated per cube yard per 24 hours - - - - 118·2 gallons.

Average Analysis of Effluent.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	·058	·41	·14
Albuminoid nitrogen	·012	·07	·036
Nitric nitrogen	1·41	·95	1·20
Oxygen absorbed from $KMnO_4$ in 4 hours	·30	·71	·50
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 8.

SHEFFIELD—*continued.*

November, 1903.

SEWAGE.—

Average daily flow - - 18,167,000 gallons - Total rainfall - - - - - 1·93 inches
Maximum daily flow - - 21,450,000 „ - Rainfall - - - - - ·08 „
Minimum daily flow - - 13,550,000 „ - Rainfall - - - - - ·03 „

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·41	4·00	2·60
Albuminoid nitrogen	·42	1·41	·806
Oxygen absorbed from $KMnO_4$ in 4 hours	6·27	12·04	9·01
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=9.

SEPTIC TANK.—

Average flow through the tank - - - - - - - - - - - 57,000 gallons.
Amount of sludge dealt with during month - - - - - - - - - - - nil.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	2·46	3·28	3·03
Albuminoid nitrogen	·35	·56	·43
Oxygen absorbed from $KMnO_4$ in 4 hours	5·45	6·50	5·97
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=4.

SETTLED SEWAGE.—

Average settlement given - - - - - - - - - - - - 2 to 3 hours.
Amount of sludge dealt with during month - - - - - - 52 tons (95% water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·29	3·06	1·90
Albuminoid nitrogen	·24	1·02	·50
Oxygen absorbed from $KMnO_4$ in 4 hours	4·40	4·93	4·61
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=5.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - - 37
Number of times secondary beds were filled during month - - - - - - 67
Amount of sewage treated per cube yard per 24 hours - - - - - - - ——

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·06	·41	·27
Albuminoid nitrogen	·035	·082	·062
Nitric nitrogen	2·64	1·05	1·53
Oxygen absorbed from $KMnO_4$ in 4 hours	.44	·74	·54
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 6.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month 54
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - 1st contact, 97·3 gallons ; 2nd contact, 191·2 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·35	·70	·51
Albuminoid nitrogen	·03	·105	·076
Nitric nitrogen	1·45	·92	1·12
Oxygen absorbed from $KMnO_4$ in 4 hours	·71	1·09	·87
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - 75
Amount of liquid treated per cube yard per 24 hours - - - - - 115·5 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·11	·28	·22
Albuminoid nitrogen	·035	·082	·054
Nitric nitrogen	1·98	·94	1·20
Oxygen absorbed from $KMnO_4$ in 4 hours	·44	1·03	·68
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 5

SHEFFIELD—*continued.*

December, 1903.

SEWAGE.—

Average daily flow	17,105,000 gallons	Total rainfall	·955 inches
Maximum daily flow	21,570,000 „	Rainfall	·15 „
Minimum daily flow	13,150,000 „	Rainfall	nil.

Average Analysis of Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·79	3·13	2·44
Albuminoid nitrogen	·60	1·11	·72
Oxygen absorbed from $KMnO_4$ in 4 hours	4·81	6·58	6·00
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=9.

SEPTIC TANK.—

Average flow through the tank - - - - - - - - - 57,000 gallons.

Amount of sludge dealt with during month - - - - - - nil.

Average Analysis of Septic Liquor.

	Best.	Worst.	Average.
Ammoniacal nitrogen	1·54	2·70	2·18
Albuminoid nitrogen	·32	·55	·43
Oxygen absorbed from $KMnO_4$ in 4 hours	4·00	5·17	4·35
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=7.

SETTLED SEWAGE.—

Average settlement given - - - - - - - - - - 2 to 3 hours.

Amount of sludge dealt with during month - - - - 60 tons (95% water).

Average Analysis of Settled Sewage.

	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	5·65	6·41	6·03
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average=2.

SHEFFIELD—*continued.*

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - - 46
Number of times secondary beds were filled during month - - - - - - 76
Amount of sewage treated per cube yard per 24 hours - - - - - - —

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - -	—	—	—
Nitric nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	—	—	—
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - -	—	—	—

Number of samples analysed for the average = .

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 81
Amount of liquid treated per cube yard per 24 hours - - - - - - - - 1st contact, 95·8 gallons; 2nd contact, 177·3 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	·41	·90	·68
Albuminoid nitrogen - - - - - - - -	·058	·105	·078
Nitric nitrogen - - - - - - - - -	1·17	·65	·93
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	·47	1·04	·68
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 7.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - 63
Amount of liquid treated per cube yard per 24 hours - - - - - 118 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - -	—	—	—
Nitric nitrogen - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	·35	·51	·43
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 2.

SHEFFIELD—*continued.*

January, 1904.

SEWAGE.—

Average daily flow	17,827,000 gallons	Total rainfall	1·575 inches.
Maximum daily flow	20,440,000 „	Rainfall	·17 „
Minimum daily flow	13,180,000 „	Rainfall	nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·53	4·11	2·29
Albuminoid nitrogen	·52	·84	·63
Oxygen absorbed from $KMnO_4$ in 4 hours	5·52	11·58	7·08
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 10.

SEPTIC TANK.—

Average flow through the tank	57,000 gallons.
Amount of sludge dealt with during month	nil.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·17	3·64	2·20
Albuminoid nitrogen	·28	·73	·40
Oxygen absorbed from $KMnO_4$ in 4 hours	3·24	4·97	4·03
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

SETTLED SEWAGE.—

Average settlement given	2 to 3 hours.
Amount of sludge dealt with during month	57 tons (97% water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average =

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - - - 40
Number of times secondary beds were filled during month - - - - - - - - 73
Amount of sewage treated per cube yard per 24 hours - - - - - - - - —

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = :

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 78
Amount of liquid treated per cube yard per 24 hours 1st contact, 88·2 gallons; 2nd contact, 176 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·17	·94	·49
Albuminoid nitrogen	·01	·105	·05
Nitric nitrogen	2·22		1·13
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = :

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - 35
Amount of liquid treated per cube yard per 24 hours - - - - - 134·7 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average= .

SHEFFIELD—*continued.*

February, 1904.

SEWAGE.—

Average daily flow	19,646,000 gallons	Total rainfall	4·645 inches.
Maximum daily flow	21,140,000 „	Rainfall	·11 „
Minimum daily flow	14,280,000 „	Rainfall	·05 „

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1.06	3·17	1·92
Albuminoid nitrogen	·31	1·12	·75
Oxygen absorbed from $KMnO_4$ in 4 hours	4·24	6·63	5·57
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 11.

SEPTIC TANK.—

Average flow through the tank	57,000 gallons.
Amount of sludge dealt with during month	11 tons 10 cwt. (83% water)

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·52	2·47	1·95
Albuminoid nitrogen	·31	·45	·36
Oxygen absorbed from $KMnO_4$ in 4 hours	3·27	3·70	3·47
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 5.

SETTLED SEWAGE.—

Average settlement given	2 to 3 hours.
Amount of sludge dealt with during month	65 tons (96% water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·05	3·17	2·01
Albuminoid nitrogen	·35	·47	·41
Oxygen absorbed from $KMnO_4$ in 4 hours	2·77	5·57	3·82
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 6.

SHEFFIELD—*continued.*

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - 63
Number of times secondary beds were filled during month - - - - 45
Amount of sewage treated per cube yard per 24 hours - - - - - —.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·11	·88	·40
Albuminoid nitrogen	·017	·105	·06
Nitric nitrogen	2·24	·87	1·58
Oxygen absorbed from $KMnO_4$ in 4 hours	·15	·61	·41
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 11.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 60
Amount of liquid treated per cube yard per 24 hours 1st contact, 77 gallons*; 2nd contact, 170.6 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·23	·58	·40
Albuminoid nitrogen	·035	·082	·047
Nitric nitrogen	1·81	·94	1·37
Oxygen absorbed from $KMnO_4$ in 4 hours	·34	·70	·57
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 5.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - 69.
Amount of liquid treated per cube yard per 24 hours - - - - - 129·3 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·11	·47	·23
Albuminoid nitrogen	·035	·047	·41
Nitric nitrogen	1·81	·82	1·56
Oxygen absorbed from $KMnO_4$ in 4 hours	·28	·65	·45
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 6.

REMARKS.—*The 1st contact bed treating septic liquor was clogged on the surface. It was, therefore, turned over from the bottom. On re-filling, a large amount of suspended matter came away, and continued to do so for several days. On February 15th, after resting, the amount of sewage per filling amounted to 131·8 gallons per cubic yard.

SHEFFIELD—*continued.*

March, 1904.

SEWAGE.—

Average daily flow - - 17,404,000 gallons - Total rainfall - - - - 1·93 inches.
Maximum daily flow - - 20,810,000 „ - Rainfall - - - - - ·015 „
Minimum daily flow - - 12,320,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·52	3·17	2·40
Albuminoid nitrogen	·38	·95	·76
Oxygen absorbed from $KMnO_4$ in 4 hours	5·87	10·75	7·32
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 13.

SEPTIC TANK.—

Average flow through the tank - - - - - - - - - 57,000 gallons.
Amount of sludge dealt with during month - - - - - - - 2 tons 17 cwts. (82 % water).

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·41	3·25	2·47
Albuminoid nitrogen	·24	·53	·40
Oxygen absorbed from $KMnO_4$ in 4 hours	4·28	5·64	4·88
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 5.

SETTLED SEWAGE.—

Average settlement given - - - - - - - - - - 2 to 3 hours.
Amount of sludge dealt with during month - - - - - - - 55 tons (97% water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·40	2·94	2·24
Albuminoid nitrogen	·24	·56	·44
Oxygen absorbed from $KMnO_4$ in 4 hours	4·17	6·04	4·98
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

FILTERS.—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during month - - - - - - 47
Number of times secondary beds were filled during month - - - - - - 62
Amount of sewage treated per cube yard per 24 hours - - - - - - - —

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·11	·76	·34
Albuminoid nitrogen	·01	·106	·061
Nitric nitrogen	2·44	·47	1·94
Oxygen absorbed from $KMnO_4$ in 4 hours	·27	·73	·41
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 13.

Contact Beds Treating Septic Liquor.—

Number of times beds were filled during month - 81.
Amount of liquid treated per cube yard per 24 hours - - - - - - - - - 1st contact, 132·9 ; 2nd contact, 167 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·17	·82	·47
Albuminoid nitrogen	·035	·105	·065
Nitric nitrogen	·87	1·75	1·45
Oxygen absorbed from $KMnO_4$ in 4 hours	·42	·90	·6
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 5.

Contact Beds Treating Settled Sewage.—

Number of times beds were filled during month - - - - - - 81.
Amount of liquid treated per cube yard per 24 hours - - - - - 117 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen	·23	·47	·34
Albuminoid nitrogen	·035	·105	·068
Nitric nitrogen	1·81	·40	1·41
Oxygen absorbed from $KMnO_4$ in 4 hours	·27	·90	·57
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 8.

SHEFFIELD—*continued.*

April, 1904.

SEWAGE—

Average daily flow - - - 16,219,000 gallons - - - Rainfall - - - 1·74 inches
Maximum daily flow - - - 19,390,000 „ - - - Rainfall - - - ·415 „
Minimum daily flow - - - 12,030,000 „ - - - Rainfall - - - nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	2·47	5·06	3·06
Albuminoid nitrogen	·64	1·20	·94
Oxygen absorbed from $KMnO_4$ in 4 hours	6·88	11·71	10·20
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 8.

SEPTIC TANK—

Average flow through the tanks - - - - - - - 57,000 gallons.
Amount of sludge dealt with during month - - - - - nil.

Average Analysis of Septic Liquor.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	1·65	4·35	2·78
Albuminoid nitrogen	·39	·89	·52
Oyxgen absorbed from $KMnO_4$ in 4 hours	5·23	6·55	5·90
Suspended solids	—	—	—
Soluble Solids	—	—	—

Number of samples analysed for the average = 8.

SETTLED SEWAGE—

Average settlement given - - - - - - - - 2 to 3 hours.
Amount of sludge dealt with during month - - - - 55 tons (96 per cent. water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	2·12	3·53	2·47
Albuminoid nitrogen	·32	·92	·56
Oxygen absorbed from $KMnO_4$ in 4 hours	4·46	6·10	5·36
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 5.

SHEFFIELD—*continued.*

FILTERS—

Contact Beds Treating Crude Sewage—

Number of times primary beds were filled during month - - - - -

Number of times secondary beds were filled during month - - - -

Amount of sewage treated per cube yard per 24 hours - - - - -

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	—	—	—
Albuminoid nitrogen - - - - - - - - -	—	—	—
Nitric nitrogen - - - - - - - - - -	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	—	—	-
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average =

Contact Beds Treating Septic Liquor—

Number of times beds were filled during month - - 81.

Amount of liquid treated per cube yard per 24 hours - 127 gals. (1st contact); 162 gals. (2nd contact).

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	·23	1·12	·43
Albuminoid nitrogen - - - - - - - - -	·06	·15	·09
Nitric nitrogen - - - - - - - - - -	1·64	·53	1·00
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	·57	1·28	·84
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 8.

Contact Beds Treating Settled Sewage—

Number of times beds were filled during month - - 81.

Amount of liquid treated per cube yard per 24 hours - 112 gallons.

Average Analysis of Effluent.

	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - - -	·23	·70	·42
Albuminoid nitrogen - - - - - - - - -	·017	·07	·048
Nitric nitrogen - - - - - - - - - -	1·87	·46	1·18
Oxygen absorbed from $KMnO_4$ in 4 hours - - - -	·41	·80	·56
Dissolved oxygen taken up in 24 hours - - - -	—	—	—
Suspended solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 5.

SHEFFIELD—*continued.*

May, 1904.

SEWAGE—

Average daily flow - - 14,990,000 gallons - Rainfall - - - - - 1·79 inches.
Maximum daily flow - - 19,730,000 „ - Rainfall - - - - - ·39 „
Minimum daily flow - - 10,860,000 „ - Rainfall - - - - - nil.

Average Analysis of Sewage.

———	Best.	Worst.	Average
Ammoniacal nitrogen	1·88	3·18	2·71
Albuminoid nitrogen	·57	1·23	·90
Oxygen absorbed from $KMnO_4$ in 4 hours	5·62	10·42	7·55
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 4.

SEPTIC TANK—

Average flow through the tank - - - - - - - - - - 57,000 gallons.
Amount of sludge dealt with during period - - - - - - - nil.

Average Analysis of Septic Liquor.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	1·88	3·88	3·18
Albuminoid nitrogen	·32	·64	·53
Oxygen absorbed from $KMnO_4$ in 4 hours	5·47	6·37	5·98
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 4.

SETTLED SEWAGE—

Average settlement given - - - - - - - - - - 2 to 3 hours
Amount of sludge dealt with during month - - - - - 50 tons (97·5 per cent. water)

Average Analysis of Settled Sewage.

———	Best.	Worst.	Average.
Ammoniacal nitrogen	2·12	2·82	2·47
Albuminoid nitrogen	·32	·78	·56
Oxygen absorbed from $KMnO_4$ in 4 hours	4·86	6·46	5·70
Suspended solids	—	—	—
Soluble solids	—	—	—

Number of samples analysed for the average = 4.

SHEFFIELD—*continued.*

FILTERS—

Contact Beds Treating Crude Sewage.—

Number of times primary beds were filled during the month - - - - —

Number of times secondary beds were filled during the month - - - - —

Amount of sewage treated per cube yard per 24 hours - - - - —

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = —

Contact Beds Treating Septic Liquor—

Number of times beds were filled during month - 81.

Amount of liquid treated per cube yard per 24 hours - - - - - - - - 122 gallons (1st contact); 163 gallons (2nd contact).

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·12	1·00	·56
Albuminoid nitrogen	·02	·15	·10
Nitric nitrogen	1·23	·58	·78
Oxygen absorbed from $KMnO_4$ in 4 hours	·28	1·40	·85
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

Contact Beds Treating Settled Sewage—

Number of times beds were filled during month - 81.

Amount of liquid treated per cube yard per 24 hours - - - - - - - - 117 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·18	·65	·32
Albuminoid nitrogen	·03	·15	·08
Nitric nitrogen	1·34	·81	·98
Oxygen absorbed from $KMnO_4$ in 4 hours	·28	·74	·44
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 4.

SHEFFIELD—*continued.*

June, 1904.

SEWAGE—

Average daily flow	- - 15,059,000 gallons	-	Rainfall	- - - - -	1·11 inches
Maximum daily flow	- - 18,940,000 „		Rainfall	- - - - -	·56 „
Minimum daily flow	- - 10,070,000 „	-	Rainfall	- - - - -	nil.

Average Analysis of Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - -	2·35	3·88	2·71
Albuminoid nitrogen - - - - - - -	·45	·89	·70
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	6·57	12·15	8·58
Suspended solids - - - - - - - - -	—	—	—
Soluble solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 6.

SEPTIC TANK—

Average flow through the tank - - - - - - - -	57,000 gallons.
Amount of sludge dealt with during month - - - - -	nil.

Average Analysis of Septic Liqour.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - -	2·47	3·76	2·82
Albuminoid nitrogen - - - - - - -	·21	·57	·41
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	4·38	6·50	5·58
Suspended solids - - - - - - - - -	—	—	—
Soluble solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 6.

SETTLED SEWAGE—

Average settlement - - - - - - -	2 to 3 hours.
Amount of sludge dealt with during month - - -	51 tons (97 per cent. water).

Average Analysis of Settled Sewage.

——	Best.	Worst.	Average.
Ammoniacal nitrogen - - - - - - -	1·53	2·94	2·23
Albuminoid nitrogen - - - - - - -	·28	·74	·43
Oxygen absorbed from $KMnO_4$ in 4 hours - - -	4·66	5·66	4·96
Suspended solids - - - - - - - - -	—	—	—
Soluble solids - - - - - - - - -	—	—	—

Number of samples analysed for the average = 6

SHEFFIELD—*continued.*

FILTERS—

Contact Beds Treating Crude Sewage—

Number of times primary beds were filled during month - - - - - - -

Number of times secondary beds were filled during month - - - - - - - —

Amount of sewage treated per cube yard per 24 hours - - - - - - - - - —

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	—	—	—
Albuminoid nitrogen	—	—	—
Nitric nitrogen	—	—	—
Oxygen absorbed from $KMnO_4$ in 4 hours	—	—	—
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = —.

Contact Beds Treating Septic Liquor—

Number of times beds were filled during month - 81.

Amount of liquid treated per cube yard per 24 hours - - - - - - - - - 121 gallons (1st contact); 166 gallons (2nd contact).

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·18	·59	·42
Albuminoid nitrogen	·03	·10	·07
Nitric nitrogen	2·06	1·23	1·51
Oxygen absorbed from $KMnO_4$ in 4 hours	·42	1·52	1·01
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 6.

Contact Beds Treating Settled Sewage—

Number of times beds were filled during month - - - - - - - 81.

Amount of liquid treated per cube yard per 24 hours- - - - - - 117 gallons.

Average Analysis of Effluent.

——	Best.	Worst.	Average.
Ammoniacal nitrogen	·12	·88	·41
Albuminoid nitrogen	·02	·14	·07
Nitric nitrogen	1·64	·76	1·31
Oxygen absorbed from $KMnO_4$ in 4 hours	·28	1·41	·63
Dissolved oxygen taken up in 24 hours	—	—	—
Suspended solids	—	—	—

Number of samples analysed for the average = 6.

SHEFFIELD—*continued.*

EXPERIMENTS ON SEDIMENTATION OF RAW SEWAGE WITHOUT CHEMICALS.

SUSPENDED SOLIDS—

Results in Parts per 100,000.

Date.	Sewage.	Date.	Settled Sewage.	Date.	1st Contact Effluent.
1901.		1901.		1901.	
		August 26	8·71 (6 samples).		
		September 12	4·94 (5 samples).		
October 22	58·21	October 22	20·29	October 22	3·57
,, 23	68·21	,, 23	14·29	,, 23	5·00
,, 30	56·43	,, 30	16·79	,, 30	7·14
,, 31	48·29	,, 31	11·43	,, 31	7·29
November 20	44·29	November 20	3·57	November 20	1·90
,, 23		,, 23	4·00	,, 23	2·86
,, 28		,, 28	7·86	,, 28	4·29
,, 29	25·71	,, 29	4·71	,, 29	2·86
December 4	60·00	December 4	6·43	December 4	1·86
,, 5	25·86	,, 5	5·00	,, 5	5·61
,, 11	26·29	,, 11	3·43	,, 11	0·94
,, 12	28·57	,, 12	6·43	,, 12	0·86
,, 18	33·57	,, 18	7·86	,, 18	2·86
,, 20	21·43	,, 20	2·14	,, 20	3·33
1902.		1902.		1902.	
January 2	28·64	January 2	15·71	January 2	2·19
,, 3	38·57	,, 3	4·57	,, 3	1·61
,, 14	52·86	,, 14	7·86	,, 14	0·94
,, 15	44·29	,, 15	11·00	,, 15	0·47
,, 22	56·43	,, 22	5·00	,, 22	0·96
,, 23	64·43	,, 23	5·71	,, 23	4·77
,, 29	40·21	,, 29	21·43	,, 29	3·86
,, 30	18·71	,, 30	16·43	,, 30	9·23
February 6	24·57	February 6	12·14	February 6	6·66
,, 7	49·71	,, 7	12·14	,, 7	5·71
,, 12	41·57	,, 12	11·14	,, 12	6·19
,, 13	42·86	,, 13	12·86	,, 13	3·80
,, 26	45·00	,, 26	5·00	,, 26	1·33
,, 27	32·29	,, 27	13·57	,, 27	0·61
March 13	46·43	March 13	7·86	March 13	2·86
,, 19	100·14	,, 19	13·21	,, 19	7·00
,, 20	75·00	,, 20	15·01	,, 20	2·04
April 2	89·43	April 2	17·57	April 2	1·33
,, 3	85·71	,, 3	27·71	,, 3	2·19
,, 9	64·43	,, 9	10·00	,, 9	1·43
,, 10	54·29	,, 10	31·86	,, 10	8·66
,, 16	66·57	,, 16	16·43	,, 16	6·57

SHEFFIELD—*continued.*

EXPERIMENTS ON SEDIMENTATION OF RAW SEWAGE WITHOUT CHEMICALS—*continued.*

SUSPENDED SOLIDS—

Results in Parts per 100,000.

Date.	Sewage.	Date.	Settled Sewage.	Date.	1st Contact Effluent.
1902.		1902.		1902.	
April 17	38·57	April 17	4·00	April 17	2·09
May 14	69·00	May 14	3·71	May 14	4·00
,, 15	35·00	,, 15	11·14	,, 15	3·37
,, 28	58·29	,, 28	3·43	,, 28	1·90
June 4	46·29	June 4	6·57	June 4	0·86
,, 5	35·71	,, 5	2·14	,, 5	0·47
,, 11	44·29	,, 11	9·29	,, 11	—
,, 12	138·57	,, 12	8·57	,, 12	6·00
,, 18	41·36	,, 18	13·57	,, 18	—
,, 19	37 86	,, 19	17·43	,, 19	3·9
July 2	41·43	July 2	3·57	July	1·33
,, 3	38·57	,, 3	5·71	,,	3·80
August 13	42·14	August 13	23·14	August 13	5·51
,, 14	57·21	,, 14	10·71	,, 14	6·19
,, 20	74·43	,, 20	7·71	,, 20	2·57
,, 21	39·00	,, 21	9·14	,, 21	2·86
,, 27	88·71	,, 27	19·86	,, 27	5·71
,, 28	23·50	,, 28	13·57	,, 28	1·90
October 9	48·29	October 9	12·86	October 9	4·77
,, 23	52·00	,, 23	16·00	,, 23	5·90
Average	50·23	Average	10·76	Average	3·59

SHEFFIELD—*continued.*

SEPTIC TANK EXPERIMENTS.

SUSPENDED SOLIDS—

Results in Parts per 100,000.

Date.	Crude Sewage.	Date.	Septic Tank Effluent.	Date.	Fine Clinker Effluent.
1900.		1900.			
June 10	77·00	July 31	9·00		
,, 11	123·00	August 1	14·00		
,, 12 D	65·00	,, 2	11·90		
,, 12 N	23·50	,, 15	10·50		
,, 16 D	68·93	,, 18	13·50		
,, 16 N	36·50	,, 19	15·49		
		1901.			
,, 19	27·00	January 10	16·30		
,, 22	28·50	,, 13	12·00		
,, 25	77·00	,, 14	10·20		
,, 26 D	32·50	,, 15	5·60		
,, 26 N	26·00	,, 17	21·00	1901.	
,, 28	12·24	,, 22	11·20	January 24	3·80
1901.		,, 23	5 20	,, 28	1·33
January 28	17·23			,, 29	0·90
,, 31	25·84			,, 30	3·33
February 4	30·67			,, 30	1·94
,, 5	36·37				
,, 6 D	82·14				
,, 6 N	17·86				
,, 10	19·07				
,, 12	19·86	February 12	13·50		
,, 13	40·43	,, 13	10·03		
,, 20	47·50	,, 14	7·49		
,, 21 D	97·36	,, 20	20·57		
,, 21 N	67·93	,, 21	15·14		
,, 24	35·71	,, 24	19·64		
,, 28	47·86	,, 28	20·07		
March 4	45·29	March 4	21·07		
,, 7	70·00	,, 7	19·57		
,, 12	35·14	,, 12	25·86		
,, 13	39 86	,, 13	19·36		
,, 17	43·57	,, 17	36·64		
,, 19	24·79	,, 19	21·36		
,, 13	39·86	,, 13	19·36	March 13	2·81
,, 17	43·57	,, 17	36·64	,, 17	—
,, 19	24·79	,, 19	21·36	,, 19	0·53
May 7	50·00	May 7	17·00	May 7	1·86
,, 8	50·21	,, 8	16·57	,, 8	1·43
,, 9	53·14	,, 9	22·29	,, 9	1·00
,, 12	43·79	,, 12	18·50	,, 12	0·81

SHEFFIELD—*continued.*

SEPTIC TANK EXPERIMENTS—*continued.*

SUSPENDED SOLIDS—

Results in Parts per 100,000.

Date.	Crude Sewage.	Date.	Septic Tank Effluent.	Date.	Fine Clinker Effluent.
1901.		1901.		1901.	
May 15	53·36	May 15	24·00	May 15	1·66
„ 16	64·57	„ 16	28·50	„ 16	1·57
„ 21	55·77	„ 21	26·29	„ 21	0·19
„ 22	74·71	„ 22	26·21	„ 22	2·76
„ 23	77·21	„ 23	26·93	„ 23	—
„ 29	—	„ 29	24·71	„ 29	1·19
„ 30	58·71	„ 30	18·36	„ 30	2·04
June 5	82·43	June 5	11·07	June 5	0·09
„ 6	12·57	„ 6	9·93	„ 6	0·47
„ 10	47·93	„ 10	11·29	„ 10	2·19
„ 11	62·21	„ 11	22·22	„ 11	3·61
„ 16	43·79	„ 16	25·00	„ 16	5·09
„ 17	64·00	„ 17	23·71	„ 17	2·14
„ 24	42·29	„ 24	7·29	„ 24	0·23
„ 25	44·14	„ 25	16·00	„ 25	0·14
July 3	59·36	July 3	15·64	July 3	0·19
„ 4	59·29	„ 4	21·57	„ 4	0·11
„ 10	49·29	„ 10	17·57	„ 10	0·47
„ 11	44·00	„ 11	8·86	„ 11	0·13
„ 17	35·14	„ 17	68·07	„ 17	1·47
„ 18	58·00	„ 18	17·43	„ 18	5·39
„ 24	56·07	„ 24	9·43	„ 24	2·09
„ 25	14·29	„ 25	20·07	„ 25	0·19
„ 31	45·14	„ 31	13·14	„ 31	0·23
August 1	42·57	August 1	9·43	August 1	0·47
„ 7	43·36	„ 7	10·86	„ 7	0·29
„ 8	58·14	„ 8	5·50	„ 8	0·29
„ 14	93·93	„ 14	13·21	„ 14	2·76
„ 15	76·07	„ 15	26·83	„ 15	6·33
„ 21	40·00	„ 21	5·29	„ 21	3·86
„ 22	50·21	„ 22	17·46	„ 22	3·23
October 2	53·43	October 2	16·86	October 2	2·09
„ 3	70·71	„ 3	17·79	—	—
(71 Samples.)	—	(66 Samples.)	—	(47 Samples.)	—
Average	49·19	—	17·79	—	1·86

SEVENTY-SEVENTH DAY.

Tuesday, 16th May, 1905

PRESENT.

The Right Hon. the EARL OF IDDESLEIGH (*Chairman*), presiding.

Major-General CONSTANTINE PHIPPS CAREY, C.B., R.E.
Colonel T. W. HARDING, J.P.
Sir WILLIAM RAMSAY, K.C.B., F.R.S.
Mr. W. H. POWER, C.B., F.R.S.
Mr. T. J. STAFFORD, F.R.C.S.I.

Mr. F. J. WILLIS (*Secretary*).

ALSO PRESENT.

Dr. A. C. HOUSTON.
Dr. GEORGE MCGOWAN.
Mr. G. B. KERSHAW.
Mr. C. C. FRYE.

Mr. H. MACLEAN WILSON, Chief Inspector of the West Riding Rivers Board, called; and Examined.

Mr. H. Maclean Wilson.

16 May 1905.

23915. (*Chairman.*) You have handed in a statement on dam sludging, and a short note on the question of standards illustrated by analyses of samples of polluted river waters in the West Riding of Yorkshire, and I propose that these should be printed in the Minutes?—Yes.

STATEMENT BY MR. H. MACLEAN WILSON WITH REGARD TO DAM SLUDGING.

There are in connection with streams in the West Riding some 1,869 dams and reservoirs, of which 510 are actually upon streams and 913 are fed from streams by sluices or goits, so that the question of cleansing them is an exceedingly important one.

Even on the clean streams the dams collect large amounts of solid matter which is carried into them from the streams in times of flood, and in the waters of the more polluted streams there are always large amounts of suspended matters which settle in the dams supplied by the stream water.

In addition to these dams there are on many of the smaller streams in the manufacturing neighbourhoods numbers of weirs for the purpose of deepening the streams so as to give facilities for drawing the water for steam purposes. Behind these weirs also large quantities of solid matter gather.

The cleansing of these dams and water-lodges is done in three different ways.

First, when a weir or dam is on one of the dirty streams where there gathers during the week a large amount of filthy solids, it is the practice to lift the sluices ponding up the water every Saturday afternoon, so as to allow the accumulated water to scour out as much as possible of this sludge. The sluice is then closed and the cleaner water coming down the stream from Saturday evening to Monday morning is collected, so that the week's work may be begun with a supply as clean as possible. This is the process of cleansing by flushing. It perhaps cannot reasonably be objected to, under proper conditions, but should be under strict regulation.

As at present it produces very gross pollution, for instance, on the Batley Beck the average flow for six days in a week was found to be at the rate of 1,850,000 gallons per day, but on Saturday at midday, when the sluices on the stream were raised, the flow increased to the rate of 25,000,000 gallons per day, and the analysis of the water taken at the time of the increased flow show solids in suspension varying from 152 to 451 parts per 100,000, and the oxygen absorbed figure from 52 to 80 parts per 100,000.

This is an extreme instance, for the Batley Beck is a greatly polluted stream only six miles in length, and having its flow checked by 75 weirs and sluices.

The second method takes several days to carry out, during which the dam cannot be used, and therefore it is often done at the Easter or Whitsuntide holidays or at the time of the local Feast, when the mills are stopped for two or three days. The photographs handed in illustrate the process. The sluices of the dam both inlet and outlet are opened, and as much as possible of the water of the stream which feeds it is turned through the dam. A number of men enter the dam, and with spades and rakes and barrows they push and carry the sludge into the current of water, by which it is washed out of the dam and into the stream. By means of planks and channels cut in the sludge the current of water is directed in turn to all parts of the dam until the accumulated sludge is washed out. This dam sludging should be absolutely prohibited, as was intended in the West Riding of Yorkshire Rivers Act of 1894.

The prohibition of the practice was expressly sought, and after strenuous opposition granted by Parlament, but the courts have upset it in two West Riding cases.

The quantities of sludge discharged into the rivers by this method are enormous. In one case it was estimated that there were 3,400 tons, and the effect upon the stream waters is very marked, as will be seen from the analyses of the waters discharged while sludging was proceeding. The sludge is deposited in all the still pools of the river below the dam, sometimes for a distance of several miles, or if a dam lower down the stream has an open shuttle, the sludge is there deposited. While the sludging is going on the water of the stream is rendered absolutely unfit for any purpose on account of the suspended matter, often of a grossly polluting character, which it carries.

The third method of cleansing dams and water-lodges is by running off the water so as to get the sludge as dry as possible, and setting men to wheel the sludge out in barrows or carts and to tip it outside the dam, and this is on the whole the general practice throughout the West Riding. The cost of doing this varies, I am told, with the depth of the dam and the availability of a place for tipping the sludge, from tenpence to half-a-crown per cube yard. The photographs show this method in operation.

Dam sludging by discharging the sludge into the streams is commonest in the West Riding on the River Don, and is generally practised there since the decision of the High Court in a case taken against a Don mill owner. Bitter complaints are made against the practice by manufacturers who themselves have no dams, but draw their water for steam purposes directly from the river, as it renders the water unfit for their use while the sludging is going on.

On the Aire and Calder the dams are generally cleaned out by barrowing, as the sludging method spoils the water for all scouring and dyeing as well as for steam purposes, and the dam sludger runs a great risk of an action for damages for spoiling the goods of a manufacturer below him on the stream.

On the remaining streams the sludging of dams to the streams is not often done, probably because the effect is so immediately apparent. One result is that when fish are present they are killed in large numbers.

There is, I am told, a method of cleansing dams by means of engine power. Two engines such as are used for steam ploughing are placed one on either side of a dam, and a large scoop or excavator is run backwards and forwards between them, hauling out the sludge on to the bank.

It has also been suggested that it would be very easy to arrange an elevator upon a raft floating in the dam by means of which the sludge could be raised and discharged to any desired point, a process which is frequently used in connection with shore reclamation at the sea side.

Measures can be adopted for preventing the bulk of the sludge from reaching the dams. In some cases at the inlet to the dam, a wall reaching nearly to the surface of the water but just underneath it is built across the dam so as to form a subsidiary pool in which the solid matters carried in from the stream can settle. If this is cleaned at frequent intervals it prevents to a great extent the solids from reaching the main part of the dam, which therefore needs cleaning at very much longer intervals. This is a practice frequently adopted in connection with public water supply reservoirs, and in connection with canals.

The method by which the stream water is conducted to a dam through a sluice or goit effects greatly the amount of solid matter which settles.

If the sluice or goit is directed up the stream so that it receives the full effect of the current in times of flood, then very large quantities of suspended matter pass into it. If on the other hand the opening is directed at right-angles to the current of the stream or down stream, the dam is not silted up nearly so quickly.

In places where sluices are placed across streams for the purpose of making a water lodge from which water can be drawn directly, they can without detriment to the users of the water be abolished, and the manufacturers can obtain a supply from a well placed alongside the stream and connected with it.

There are other processes closely related to dam sludging which increase the pollution of the streams. Banks of solid matter accumulate in the channels of streams above a weir or at the entrance to a goit, or at the intake where water is drawn for manufacturing purposes, and it is the common practice when removing these deposits to throw them back into the deeper parts of the channel. Complaints are sometimes received that by doing this the water is rendered muddy, and the deposits are passed on to the detriment of someone lower down the stream.

Many of the Yorkshire streams are used for navigation, which is carried on partly in the river channel and partly in cuts or canals from one stretch of the river to another. On the river below the intake of each of these cuts there is necessarily a weir, and it is not an uncommon practice for the navigation authorities to dredge out the solids from that part of the river bed which is navigable or even from the artificial cuts and to deposit them immediately above or over one of these weirs so that they are carried down the river into the part which is not used for navigation.

NOTE BY Mr. H. MACLEAN WILSON ON THE QUESTION OF STANDARDS FOR DIFFERENT STREAMS.

Mr. H. Maclean Wilson.

16 May 1905.

On the general question of fixed standards I think I have nothing to add to what I have already said to the Commission.

With regard to the suggestion that a Rivers Board should have powers to fix standards (subject to confirmation) for different parts of their districts, I think it would lead to grave disputes, and it would be better if standards are to be fixed, that they should be fixed by a central authority.

In the West Riding I do not think it is possible to apply different standards to the different streams. At present, no doubt, the condition of the streams varies greatly when one stream is compared with another or one part with another part of the same stream, but this ought to be remedied and all the streams ought to be rendered free from nuisance and fit for any ordinary purpose except that of domestic water supply. As a matter of fact there is, I believe, only one water supply drawn from a stream in the West Riding, except in the cases of upland gathering grounds at the heads of the valleys.

I present tables of analyses of samples of the polluted rivers in the Riding, which have been taken quarterly over the last six years. The points at which samples have been taken are marked with an X on the accompanying plan. The worst of those samples are from the River Aire, which has been tested at four points—Stocksbridge, Saltaire, Apperley Bridge, and Methley. (See map.)

Above Stocksbridge there are only two Urban Districts, Skipton and Silsden. Between Stocksbridge and Saltaire there are six Urban Districts, including the Non-County Borough of Keighley. Between Saltaire and Apperley Bridge there are six Urban Districts, including the County Borough of Bradford, and between Apperley Bridge and Methley there are ten Urban Districts, including the County Borough of Leeds and the Non-County Boroughs of Pudsey and Morley.

It will be seen that in spite of some pollution from Skipton, Keighley, and Bingley (which is at present being dealt with) the river down as far as Saltaire is in very fair condition. It is in fact full of trout and coarse fish. Between Saltaire and Apperley Bridge it receives comparatively little polluting matter, except the half purified sewage of Bradford and the trade refuse from some of the manufactories in the neighbourhood.

Between Apperley Bridge and Methley little more pollution is added to it except the partially purified sewage of Leeds and Morley, the other districts being fairly well provided with purification works, which deal with trade refuse as well as domestic sewage. As a matter of fact, if the sewage and trade refuse of Bradford and Leeds were efficiently purified, and works that are now in hand in the other Districts were completed, there seems to be no reason why the condition of the river below Saltaire should not be quite as good as that above.

It would manifestly therefore be unfair, on account of the present condition of the river above and below Saltaire, to establish different standards for these respective portions.

The same argument applies to the other polluted rivers in the Riding.

TABLE I.—ANALYSES OF WATER OF RIVER AIRE AT STOCKBRIDGE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution. Loss on Ignition.	Ash.	Total.	Solids in Suspension only. Loss on Ignition.	Ash.	Total.	Chlorides (as Na Cl).	Nitrogen. Nitric.	Ammoniacal (from Free and Saline Amm.)	Albuminoid (Wanklyn.)	Oxygen absorbed in 4 hours at 80° F.	Hardness. Temp.	Perm.	Total.	Rainfall in ins. at selected stations. During preceding two days.	During preceding week.
2nd September, 1898	3. 0 p.m.	—	4·8	17·1	21·9	—	—	—	2·30	—	0·003	0·016	0·29	8·5	3·3	11·8	0·01	0·78
2nd December, 1898	3. 0 p.m.	13·0	4·4	19·4	23·8	—	—	—	1·80	0·16	0·012	0·012	0·20	10·3	4·5	14·8	0·10	0·55
3rd March, 1899	2. 0 p.m.	24·0	4·5	20·1	24·6	—	—	—	2·60	0·15	0·052	0·016	0·13	10·4	5·3	15·7	0·00	0·00
2nd June, 1899	2. 0 p.m.	18·0	4·0	19·6	23·6	—	—	—	2·90	0·07	0·017	0·015	0·19	11·4	2·6	14·0	0·00	0·00
1st September, 1899	2.50 p.m.	13·5	2·8	17·8	20·6	—	—	—	2·63	0·06	0·009	0·021	0·28	6·5	5·3	11·8	0·65	1·26
1st December, 1899	2. 0 p.m.	24·0	4·0	19·2	23·2	—	—	—	3·20	0·13	0·333	0·014	0·16	9·0	7·5	16·5	0·00	0·05
2nd March, 1900	2.30 p.m.	24·0	1·6	18·8	20·4	—	—	—	2·19	0·19	0·013	0·012	0·16	7·5	7·5	15·0	0·06	1·11
1st June, 1900	2.30 p.m.	14·0	3·0	21·2	24·2	—	—	—	2·92	0·02	0·004	0·035	0·22	11·2	6·0	17·2	0·00	0·41
7th September, 1900	2.30 p.m.	21·0	7·0	17·0	24·0	—	—	—	2·34	0·07	0·024	0·017	0·19	9·8	6·7	16·5	0·00	0·27
7th December, 1900	2.30 p.m.	12·5	4·0	18·8	22·8	—	—	—	1·87	0·07	0·010	0·018	0·31	7·0	8·0	15·0	0·73	1·47
1st March, 1901	2.30 p.m.	3·0	5·2	24·6	29·8	2·2	8·6	10·8	2·34	0·11	0·022	0·039	0·53	4·5	8·0	12·5	0·13	0·29
7th June, 1901	2.30 p.m.	23·0	4·4	22·8	27·2	—	—	—	2·60	0·07	0·028	0·029	0·22	8·0	6·8	14·8	0·04	0·22
6th September, 1901	2.30 p.m.	15·0	3·2	17·6	20·8	—	—	—	2·20	0·07	0·008	0·029	0·22	10·0	5·0	15·0	0·00	0·10
6th December, 1901	2.30 p.m.	21·0	3·4	23·0	26·4	—	—	—	2·50	0·10	0·140	0·019	0·19	6·5	10·5	17·0	0·03	0·05
7th March, 1902	2.30 p.m.	24·0	2·8	22·4	25·2	—	—	—	2·50	0·08	0·022	0·010	0·12	9·5	7·0	16·5	0·00	0·03
6th June, 1902	2.30 p.m.	13·5	3·2	22·0	25·2	—	—	—	3·00	Nil	0·004	0·034	0·23	6·0	6·5	12·5	0·14	0·72
5th September, 1902	2.30 p.m.	—	2·8	21·2	24·0	—	—	—	2·70	0·08	0·004	0·018	0·18	6·1	9·5	15·6	0·26	0·31
5th December, 1902	2.30 .pm.	21·0	2·8	22·4	25·2	—	—	—	2·50	0·11	0·020	0·016	0·16	8·7	8·5	17·2	0·05	1·55
6th March, 1903	2. 0 p.m.	17·0	2·4	19·2	21·6	—	—	—	2·50	0·11	0·015	0·013	0·18	8·3	8·1	16·4	0·29	1·25
5th June, 1903	2.30 p.m.	15·0	3·6	20·4	24·0	—	—	—	2·50	0·03	0·018	0·018	0·19	8·0	14·0	22.0	0·00	0·02
4th September, 1903	2.30 p.m.	21·5	2·8	19·6	22·4	—	—	—	2·00	0·04	0·012	0·014	0·34	8·2	7·4	15·6	0·77	1·25
4th December, 1903	2.30 p.m.	6·0	4·2	17·2	21·4	0·6	3·5	4·1	1·75	0·06	0·013	0·018	0·44	3·5	9·0	12·5	0·13	0·58
4th March, 1904	2.30 p.m.	17·5	5·9	17·9	23·8	0·3	0·3	0·6	2·50	0·06	0·020	0·012	0·19	9·1	8·1	17·2	0·24	0·82
3rd June, 1904	2.30 p.m.	24·0	5·2	20·8	26·0	0·1	0·4	0·5	2·00	0·04	0·020	0·014	0·23	7·7	10·3	18·0	0·57	1·38
2nd September, 1904	2.30 p.m.	24·0	3·1	21·9	25·0	0·1	0·6	0·7	2·50	0·08	0·026	0·013	0·25	8·9	6·7	15·6	0·00	0·00
2nd December, 1904	2.30 p.m.	14·5	5·7	16·4	22·2	0·2	0·8	1·0	2·00	0·07	0·031	0·019	0·27	7·3	6·7	14·0	0·01	0·02
AVERAGES:																		
March Samples	—	18·2	3·7	20·5	24·2	0·4	1·5	1·9	2·44	0·117	0·024	0·017	0·22	8·2	7·3	15·5	0·12	0·58
June Samples	—	17·9	3·9	21·1	25·0	0·01	0·07	0·08	2·65	0·040	0·015	0·24	0·21	8·7	7·7	16·4	0·12	0·46
September Samples	—	19·0	3·8	18·9	22·7	0·01	0·08	0·09	2·38	0·067	0·012	0·018	0·25	8·3	6·3	14·6	0·24	0·56
December Samples	—	16·0	4·1	19·5	23·6	0·11	0·62	0·73	2·23	0·100	0·037	0·017	0·25	7·5	8·0	15·5	0·15	0·61
TOTAL SAMPLES	—	17·7	3·9	19·9	23·8	0·13	0·55	0·68	2·42	0·082	0·022	0·019	0·23	8·1	7·3	15·4	0·16	0·56

Table II.—Analyses of Water of River Aire at Saltaire

Results Expressed in Parts per 100,000.

DATE.	Time. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September 1898	11. 0 a.m.	—	6·3	17·5	23·8	—	—	—	2·30	—	0·014	0·026	0·42	9·4	3·8	13·2	0·01	0·78
2nd December, 1898	11. 0 a.m.	10·5	3·6	17·3	20·9	—	—	—	2·10	0·18	0·018	0·014	0·19	7·3	5·5	12·8	0·10	0·55
3rd March, 1899	11. 0 a.m.	19·0	4·5	19·9	24·4	—	—	—	2·93	0·14	0·064	0·026	0·18	9·7	4·6	14·3	0·00	0·00
2nd June, 1899	11. 0 a.m.	23·0	2·3	20·9	23·2	—	—	—	2·63	0·07	0·054	0·025	0·25	8·0	4·5	12·5	0·00	0·00
1st September, 1899	11. 0 a.m.	11·0	3·6	23·8	27·4	—	—	—	3·51	0·11	0·005	0·030	0·40	11·0	4·6	15·6	0·65	1·26
1st December, 1899	11. 0 a.m.	24·0	2·7	18·5	21·2	—	—	—	2·92	0·05	0·051	0·017	0·20	7·5	7·5	15·0	0·00	0·05
1st March, 1900	11. 0 a.m.	15·5	2·8	18·6	21·4	—	—	—	2·46	0·06	0·026	0·021	0·26	6·0	9·0	15·0	0·06	1·11
1st June, 1900	11. 0 a.m.	11·0	3·8	24·6	28·4	—	—	—	3·21	0·112	0·002	0·038	0·34	8·6	8·1	16·7	0·00	0·41
7th September, 1900	11. 0 a.m.	12·5	8·4	17·9	26·3	—	—	—	2·34	0·10	0·039	0·026	0·24	4·8	10·7	15·5	0·00	0·27
7th December, 1900	11. 0 a.m.	8·5	4·0	19·2	23·2	—	—	—	2·34	0·10	0·014	0·014	0·36	3·8	9·5	13·3	0·73	1·47
1st March, 1901	11. 0 a.m.	4·0	8·4	24·8	33·2	2·4	8·8	11·2	2·63	0·12	0·051	0·067	0·55	4·5	8·0	12·5	0·13	0·29
7th June, 1901	11. 0 a.m.	17·5	8·0	22·0	30·0	2·0	0·8	2·8	3·00	0·09	0·047	0·043	0·32	4·5	10·3	14·8	0·04	0·22
6th September, 1901	11. 0 a.m.	13·5	4·4	24·0	28·4	1·0	0·8	1·8	3·50	0·18	0·009	0·044	0·37	5·0	10·5	15·5	0·00	0·10
6th December, 1901	11. 0 a.m.	19·0	3·8	19·8	23·6	—	—	—	3·00	0·12	0·137	0·025	0·25	3·5	9·5	13·0	0·03	0·05
7th March, 1902	11. 0 a.m.	22·0	3·2	20·4	23·6	—	—	—	3·00	0·07	0·060	0·015	0·16	6·5	8·0	14·5	0·00	0·03
6th June, 1902	11. 0 a.m.	18·5	4·4	22·8	27·2	—	—	—	3·00	0·12	0·005	0·040	0·26	4·0	11·0	15·0	0·14	0·72
5th September, 1902	11. 0 a.m.	—	3·6	20·4	24·0	—	—	—	3·00	0·10	0·038	0·032	0·28	3·7	10·3	14·0	0·26	0·31
5th December, 1902	11. 0 a.m.	18·5	3·2	20·8	24·0	—	—	—	2·50	0·16	0·034	0·026	0·22	5·2	9·6	14·8	0·05	1·55
6th March, 1903	11. 0 a.m.	13·0	4·0	17·2	21·2	—	—	—	2·50	0·12	0·017	0·018	0·24	6·6	7·4	14·0	0·29	1·25
5th June, 1903	11. 0 a.m.	16·0	3·6	21·2	24·8	—	—	—	3·00	0·08	0·058	0·029	0·24	3·1	13·3	16·4	0·000	0·02
4th September, 1903	11. 0 a.m.	16·5	7·4	15·2	22·6	0·2	0·8	1·0	2·00	0·06	0·012	0·018	0·42	3·7	10·3	14·0	0·77	1·25
4th December, 1903	11. 0 a.m.	4·5	4·9	20·5	25·4	1·7	6·1	7·8	2·00	0·09	0·016	0·026	0·52	0·8	9·5	10·3	0·13	0·58
4th March, 1904	11. 0 a.m.	15·0	5·5	18·9	24·4	0·3	0·5	0·8	2·50	0·10	0·034	0·018	0·23	9·0	7·4	16·4	0·24	0·82
3rd June, 1904	11. 0 a.m.	24·0	4·4	20·0	24·4	0·2	0·6	0·8	2·50	0·06	0·032	0·018	0·31	6·8	9·6	16·4	0·57	1·38
2nd September, 1904	11. 0 a.m.	13·0	4·3	23·8	28·1	0·5	1·0	1·5	3·00	0·12	0·029	0·024	0·36	5·2	8·9	14·1	0·00	0·00
2nd December, 1904	11. 0 a.m.	18·0	5·0	17·6	22·6	0·1	0·5	0·6	2·50	0·09	0·050	0·023	0·29	5·9	7·4	13·3	0·01	0·02
Averages:																		
March Samples	—	14·7	4·7	20·0	24·7	0·45	1·54	1·99	2·67	0·10	0·042	0·027	0·27	7·0	7·4	14·4	0·12	0·58
June Samples	—	18·3	4·4	21·9	26·3	0·37	0·23	0·60	2·89	0·09	0·033	0·032	0·29	5·8	9·5	15·3	0·12	0·46
September Samples	—	13·3	5·4	20·4	25·8	0·23	0·57	0·60	2·80	0·11	0·021	0·029	0·36	6·1	8·4	14·5	0·24	0·57
December Samples	—	14·7	3·9	19·1	23·0	0·25	0·95	1·20	2·48	0·11	0·046	0·021	0·29	4·8	8·3	13·1	0·15	0·61
Total Samples	—	15·3	4·6	20·3	24·9	0·32	0·76	1·08	2·70	0·10	0·035	0·027	0·30	5·9	8·4	14·3	0·16	0·56

TABLE III.—ANALYSES OF WATER OF RIVER AIRE AT APPERLEY BRIDGE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	11. 0 a.m.	—	12·6	30·6	43·2	—	—	—	5·50	—	0·388	0·153	2·00	10·7	4·5	15·2	0·01	0·78
2nd December, 1898	11. 0 a.m.	5.5	6·8	22·1	28·9	—	—	—	2·81	·10	0·120	0·074	0·69	9·8	5·7	15·5	0·10	0·55
3rd March, 1899	11. 0 a.m.	3.5	10·5	33·6	44·1	2·4	0·2	2·6	4·70	·03	0·310	0·140	1·40	9·9	7·4	17·3	0·00	0·00
2nd June, 1899	11. 0 a.m.	3.5	9·6	36·4	46·0	3·3	2·5	5·8	5·57	—	0·330	0·150	1·85	8·6	7·1	15·7	0·00	0·00
1st September, 1899	11. 0 a.m.	1.0	14·5	50·7	65·2	5·3	6·2	11·5	7·31	—	0·724	0·255	3·10	9·3	10·3	19·6	0·65	1·26
1st December, 1899	11. 0 a.m.	2.5	13·2	36·0	49·2	6·8	0·8	7·6	4·97	—	0·304	0·170	1·70	11·5	8·0	19·5	0·00	0·05
2nd March, 1900	11. 0 a.m.	6.0	6·8	24·0	30·8	2·0	0·4	2·4	2·92	·15	0·059	0·045	0·71	3·5	12·0	15·5	0·06	1·11
1st June, 1900	11. 0 a.m.	1.5	15·6	49·2	64·8	9·2	1·6	10·8	7·90	—	0·703	0·318	3·27	9·3	10·3	19·6	0·00	0·41
7th September, 1900	11. 0 a.m.	3.0	11·4	35·8	47·2	3·2	1·0	4·2	5·85	—	0·422	0·198	1·46	5·5	12·5	18·0	0·00	0·27
7th December, 1900	11. 0 a.m.	5.5	8·0	19·0	27·0	1·7	2·9	4·6	2·75	0·05	0·043	0·067	0·67	5·0	9·0	14·0	0·73	1·47
1st March, 1901	11. 0 a.m.	1.5	17·6	41·2	58·8	9·6	19·2	28·8	3·80	0·04	0·130	0·260	1·76	6·0	10·5	16·5	0·13	0·29
7th June, 1901	11. 0 a.m.	1.5	23·0	53·0	76·0	8·0	3·0	11·0	8·20	Nil	0·880	0·380	3·70	5·3	15·0	20·3	0·04	0·22
6th September, 1901	11. 0 a.m.	1.0	110·0	167·0	277·0	101·0	104·0	205·0	9·50	Nil	1·300	2·190	20·00	19·0	7·5	26·5	0·00	0·10
6th December, 1901	11. 0 a.m.	3.5	10·6	31·8	42·4	2·6	1·8	4·4	4·50	Nil	0·380	0·130	1·30	4·5	12·5	17·0	0·03	0·05
7th March, 1902	11. 0 a.m.	2.0	14·2	36·4	50·6	6·16	1·44	7·6	4·20	Nil	0·260	0·240	2·40	3·5	13·0	16·5	0·00	0·03
6th June, 1902	11. 0 a.m.	1.5	17·0	51·9	68·9	9·0	1·9	10·9	7·50	Nil	0·820	0·320	3·60	7·0	15·0	22·0	0·14	0·72
5th September, 1902	11. 0 a.m.	2.5	16·4	68·8	85·2	6·0	2·4	8·4	9·50	Nil	1·200	0·350	4·20	4·0	17·2	21·2	0·26	0·31
5th December, 1902	11. 0 a.m.	9.0	6·8	26·0	32·8	1·8	1·0	2·8	3·60	0·20	0·120	0·060	0·73	2·8	14·4	17·2	0·05	1·55
6th March, 1903	11. 0 a.m.	6.0	6.5	22·9	29·4	1·7	·9	2·6	3·00	0·20	0·053	0·055	0·76	2·3	13·3	15·6	0·29	1·25
5th June, 1903	11. 0 a.m.	4.2	12·0	44·2	56·2	2·0	1·2	3·2	6·37	Nil	0·449	0·130	2·04	1·6	15·6	17·2	0·00	0·02
4th September, 1903	10. 0 a.m.	11.5	5·0	22·6	27·6	0·6	1·0	1·6	3·00	Trace	0·060	0·038	0·81	5·2	8·8	14·0	0·77	1·25
4th December, 1903	11. 0 a.m.	3.5	5·8	25·4	31·2	3·0	8·2	1·2	2·25	0·07	0·050	0·070	0·80	Nil	11·0	11·0	0·13	0·58
4th March, 1904	11. 0 a.m.	6.5	6·8	25·0	31·8	0·8	0·6	11·4	3·50	0·12	0·100	0·038	0·60	8·5	10·3	18·8	0·24	0·82
3rd June, 1904	11. 0 a.m.	5.0	11·6	26·2	37·8	1·6	1·2	2·8	3·75	Nil	0·176	0·070	1·27	0·8	16·4	17·2	0·57	1·38
2nd September, 1904	11. 0 a.m.	1.7	16·5	51·2	67·7	5·5	2·2	7·7	8·25	Nil	0·800	0·158	3·10	2·3	13·3	15·6	0·00	0·00
2nd December, 1904	11. 0 a.m.	8.0	7·8	20·8	28·6	1·0	0·8	1·8	3·25	0·07	0·138	0·045	0·66	6·0	8·1	14·1	0·01	0·02
AVERAGES:																		
March Samples	—		4·2	10·4	30·5	40·9	3·78	3·79	7·57	3·69	0·09	0·152	0·130	1·27	5·6	11·1	16·7	0·12	0·58
June Samples	—		2·9	14·8	43·5	58·3	5·52	1·90	7·42	6·55	0·00	0·560	0·228	2·62	5·4	13·2	18·6	0·12	0·46
September Samples	—		3·4	26·6	61·0	87·6	17·37	16·67	34·04	6·99	0·00	0·699	0·477	4·95	8·0	10·6	18·6	0·24	0·57
December Samples	—		5·4	8·4	25·9	34 3	2·40	2·22	4·62	3·45	0·07	0·165	0·088	0·94	5·7	9·8	15·5	0·15	0·61
TOTAL SAMPLES	—		4·0	15·2	40·5	55·	7·47	6·40	13·87	5·17	0·04	0·397	0·235	2·48	6·2	11·1	17·3	0·16	0·56

TABLE IV.—ANALYSES OF WATER OF RIVER AIRE AT METHLEY, ONE MILE ABOVE CASTLEFORD.

Results expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	12 Noon	—	8·8	49·7	58·5	—	—	—	11·10	—	0·700	0·106	1·43	10·7	5·7	16·4	0·00	0·89
2nd December, 1898	10.30 a.m.	3·5	7·4	35·6	43·0	2·9	1·4	4·3	6·56	Nil	0·270	0·082	1·03	9·1	8·9	18·0	0·06	0·19
3rd March, 1899	11.30 a.m.	3·0	12·4	52·4	64·8	1·0	1·6	2·6	11·10	Nil	0·620	0·170	1·74	9·6	12·5	22·1	0·04	0·06
2nd June, 1899	12 Noon	3·0	10·1	50·7	60·8	2·6	1·2	3·8	11·70	Nil	0·660	0·160	1·80	11·4	11·4	22·8	1·00	0·00
1st September, 1899	11.30 a.m.	3·5	8·8	61·2	70·0	2·0	0·4	2·4	14·90	Nil	1·110	0·130	1·76	15·3	6·7	22·0	0·15	0·80
1st December, 1899	12 Noon	3·5	11·8	47·9	59·7	3·3	0·5	3·8	11·70	Nil	0·584	0·099	1·25	9·5	11·0	20·5	0·00	0·00
2nd March, 1900	11.30 a.m.	4·0	7·4	34·2	41·6	1·8	3·0	4·8	5·85	0·32	0·140	0·057	0·81	4·5	15·0	19·5	0·08	1·33
1st June, 1900	11.30 a.m.	2·5	9·8	58·8	68·6	3·0	2·8	5·8	16·38	Nil	1·170	0·175	1·77	15·6	11·0	26·6	0·00	0·00
7th September, 1900	11.30 a.m.	3·0	—	—	61·1	—	—	3·2	12·00	Nil	0·770	0·137	1·06	4·5	16·5	21·0	0·00	0·15
7th December, 1900	11.45 a.m.	5·0	11·0	22·0	33·0	2·1	4·7	6·8	3·33	0·10	0·078	0·064	0·69	1·5	12·5	14·0	0·68	1·36
1st March, 1901	12 Noon	3·0	10·2	37·0	47·2	1·2	4·0	5·2	6·43	0·04	0·380	0·150	1·30	6·5	12·5	19·0	0·28	0·51
7th June, 1901	12 Noon	1·5	19·0	57·8	76·8	4·0	2·8	6·8	15·50	Nil	1·450	0·320	2·40	7·5	13·0	20·5	0·00	0·00
6th September, 1901	12 Noon	2·0	13·0	77·0	90·0	5·7	3·8	9·5	19·00	Nil	1·960	0·290	4·96	10·0	10·5	20·5	0·00	0·00
6th December, 1901	11.45 a.m.	3·5	10·4	45·8	56·2	1·4	1·8	3·2	12·00	Nil	0·630	0·140	2·05	5·0	18·5	23·5	0·00	0·07
7th March, 1902	11.30 a.m.	2·5	8·0	51·2	59·2	3·0	2·2	5·2	9·00	Nil	0·780	0·170	2·24	4·0	15·5	19·5	0·00	0·01
6th June, 1902	12 Noon	2·0	11·3	52·7	64·0	4·1	3·9	8·0	10·50	Nil	1·030	0·220	2·60	8·0	14·5	22·5	0·03	0·88
5th September, 1902	12 Noon	2·5	12·4	64·8	77·2	4·4	3·2	7·6	14·00	Nil	1·350	0·180	2·56	8·9	14·0	22·9	0·00	0·11
5th December, 1902	12 Noon	5·0	8·6	34·8	43·4	2·6	2·8	5·4	5·60	0·26	0·220	0·100	1·03	3·6	16·8	20·4	0·02	1·13
6th March, 1903	12 Noon	5·0	10·4	26·4	36·8	3.4	1·4	4·8	5·00	0·18	0·154	0·060	0·92	4·8	14·8	19·6	0·10	0·45
5th June, 1903	12 Noon	4·7	13·6	50·0	63·6	1·6	2·0	3·6	12·25	Nil	0·860	0·120	1·18	9·0	20·6	29·6	0·00	0·07
4th September, 1903	11.30 a.m.	6·0	6·6	30·2	36·8	1·4	3·8	5·2	5·00	Slt. Tr.	0·232	0·091	1·10	5·3	10·3	15·6	0·42	0·86
4th December, 1903	11.30 a.m.	1·0	19·2	53·6	72·8	14·8	30·0	44·8	3·50	0·05	0·212	0·262	2·44	3·8	11·8	15·6	0·20	0·57
4th March, 1904	12 Noon	4·0	10·6	37·2	47·8	1·6	2·2	3·8	7·50	0·10	0·400	0·072	1·14	6·3	13·3	19·6	0·10	0·24
3rd June, 1904	12 Noon	4·0	7·5	42·5	50·0	1·5	4·5	6·0	9·75	Nil	0·475	0·090	1·26	0·8	16·4	17·2	0·01	1·28
2nd September, 1904	12 Noon	1·7	10·7	62·2	72·9	3·7	4·2	7·9	17·00	Nil	0·940	0·134	2·08	7·0	12·6	19·6	0·00	0·02
2nd December, 1904	12 Noon	5·5	10·3	32·8	43·1	1·7	1·7	3·4	7·50	0·04	0·373	0·065	1·06	7·0	11·0	18·0	0·01	0·02
AVERAGES:																		
March Samples	—	3·6	9·8	39·7	49·5	2·00	2·40	4·40	7·48	0·11	0·412	0·113	1·36	5·9	13·9	19·8	0·10	0·43
June Samples	—	2·9	11·9	52·1	64·0	2·80	2·87	5·67	12·68	0·00	0·941	0·181	1·83	8·7	14·5	23·2	0·01	0·37
September Samples	—	3·1	9·9	56·7	66·6	2·70	2·40	5·10	13·30	0·00	1·009	0·153	2·14	8·8	10·9	19·7	0·08	0·40
December Samples	—	3·9	11·3	38·9	50·2	4·12	6·12	10·24	7·17	0·06	0·338	0·116	1·36	5·6	12·9	18·5	0·14	0·48
TOTAL SAMPLES	—	3·4	10·7	46·9	57·6	2·94	3·51	6·45	10·16	0·04	0·675	0·140	1·68	7·3	12·9	20·2	0·08	0·42

Mr. H. Mackan Wilson.
16 May 1905

TABLE V.—ANALYSES OF WATER OF BRADFORD BECK AT JUNCTION WITH AIRE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	2. 0 p.m.	—	108·8	170·4	279·2	72·7	46·1	118·8	26·30	—	3·410	1·420	20·60	5·7	2·3	18·0	0·01	0·78
2nd December, 1898	2. 0 p.m.	0·5	42·0	121·4	163·4	24·6	61·4	86·0	12·30	Nil	1·200	0·760	8·70	12·7	11·0	23·7	0·10	0·55
3rd March, 1899	2. 0 p.m.	0·5	95·2	198·0	293·2	54·4	56·0	110·4	21·90	Nil	3·100	1·440	18·40	8·6	27·1	35·7	0·00	0·00
2nd June, 1899	2. 0 p.m.	1·0	73·0	133·4	206·4	45·8	23·8	69·6	21·08	Nil	2·350	0·850	15·78	21·1	14·9	36·0	0·00	0·00
1st September, 1899	2. 0 p.m.	1·0	108·0	163·0	271·0	81·0	34·0	115·0	22·80	Nil	2·340	1·380	14·20	17·2	15·6	32·8	0·65	1·26
1st December, 1899	2. 0 p.m.	1·0	72·0	163·8	235·8	46·0	56·8	102·8	14·62	Nil	2·630	1·180	13·40	16·5	18·0	34·5	0·00	0·05
2nd March, 1900	2. 0 p.m.	0·5	40·0	74·0	114·0	26·0	5·0	31·0	12·87	Nil	1·190	0·600	7·00	12·0	19·0	31·0	0·06	1·11
1st June, 1900	2. 0 p.m.	1·0	84·0	135·0	219·0	59·0	21·0	80·0	19·89	Nil	2·780	1·410	14·59	16·9	19·1	36·0	0·00	0·41
7th September, 1900	2. 0 p.m.	1·0	50·0	105·4	155·4	30·6	22·8	53·4	14·60	Nil	1·960	0·940	10·10	11·0	15·5	26·5	0·00	0·27
14th December, 1900	2. 0 p.m.	1·0	69·0	101·6	170·6	44·0	14·6	58·6	14·33	Nil	2·200	1·320	10·86	8·8	17·7	26·5	0·73	1·47
1st March, 1901	2. 0 p.m.	1·0	33·8	79·6	113·4	20·8	15·6	36·4	10·80	Nil	1·120	0·560	6·23	10·5	19·5	30·0	0·13	0·29
7th June, 1901	2. 0 p.m.	1·0	117·0	194·0	311·0	72·0	44·0	116·0	20·50	Nil	2·990	1·900	20·24	17·2	33·0	50·2	0·04	0·22
6th September, 1901	2. 0 p.m.	1·0	127·0	188·0	315·0	103·0	31·0	134·0	28·50	Nil	3·570	1·860	24·00	12·0	17·5	29·5	0·00	0·10
6th December, 1901	2. 0 p.m.	1·0	99·0	152·0	251·0	72·0	20·0	92·0	22·70	Nil	3·180	1·400	18·40	11·5	19·5	31·0	0·03	0·05
7th March, 1902	2. 0 p.m.	1·0	101·4	158·6	260·0	64·4	33·6	98·0	18·50	Nil	2·800	1·160	16·40	14·5	19·5	34·0	0·00	0·03
6th June, 1902	2. 0 p.m.	1·0	92·0	151·0	243·0	60·0	20·0	80·0	17·50	Nil	2·800	0·900	15·40	10·0	24·0	34·0	0·14	0·72
5th September, 1902	2. 0 p.m.	1·0	57·0	151·0	208·0	26·0	16·0	42·0	14·50	Nil	2·300	1·000	11·00	14·2	25·0	39·2	0·26	0·31
5th December, 1902	2. 0 p.m.	1·0	30·6	98·6	129·2	12·2	4·0	16·2	13·50	Nil	1·530	0·640	7·04	9·6	29·6	39·2	0·05	1·55
6th March, 1903	2. 0 p.m.	1·0	38·5	86·0	124·5	14·5	5·0	19·5	12·50	Nil	1·030	0·410	6·53	11·5	22·9	34·4	0·29	1·25
5th June, 1903	2. 0 p.m.	0·7	60·0	129·0	189·0	32·0	10·0	42·0	15·00	Nil	2·148	1·044	9·60	3·0	25·1	28·1	0·00	0·02
4th September, 1903	12 Noon	1·0	50·6	121·6	172·2	23·0	7·6	30·6	13·25	Nil	2·140	0·500	10·08	11·0	26·6	37·6	0·77	1·25
4th December, 1903	2. 0 p.m.	1·0	20·4	66·0	86·4	8·4	8·0	16·4	10·50	Nil	1·120	0·240	4·62	5·4	21·2	26·6	0·13	0·58
4th March, 1904	2. 0 p.m.	0·7	42·8	112·8	155·6	16·4	4·2	20·6	14·50	Nil	1·540	0·685	9·48	7·8	26·6	34·4	0·24	0·82
3rd June, 1904	2. 0 p.m.	1·0	58·0	134·0	192·0	31·0	9·0	40·0	15·50	Nil	2·080	0.652	12·16	15·8	26·6	42·4	0·57	1·38
2nd September, 1904	2. 0 p.m.	1·0	70·6	144·4	215·0	44·6	13·4	58·0	19·50	Nil	2·330	0·746	11·20	10·0	22·9	32·9	0·00	0·00
2nd December, 1904	2. 0 p.m.	0·5	48·6	105·6	154·2	26·0	14·6	40·6	16·00	Nil	2·174	0·650	11·24	7·2	16·4	23·6	0·01	0·02
AVERAGES:																		
March Samples	—	0·8	58·6	118·2	176·8	32·7	19·9	52·6	15·18	Nil	1·800	0·809	10·71	10·8	22·4	33·2	0·12	0·58
June Samples	—	0·9	80·7	146·1	226·8	50·0	21·3	71·3	18·24	Nil	2·525	1·126	14·63	14·0	23·6	37·8	0·12	0·46
September Samples	—	1·0	81·7	149·1	230·8	54·4	24·4	78·8	19·92	Nil	2·580	1·121	14·45	11·6	19·3	30·9	0·24	0·57
December Samples	—	0·9	54·5	115·6	170·1	33·3	25·6	58·9	14·85	Nil	2·005	0·88	10·59	10·2	19·1	29·3	0·15	0·61
TOTAL SAMPLES	—	0·9	68·8	132·2	201·0	42·7	23·0	65·7	17·07	Nil	2·231	0·986	12·59	11·61	21·0	32·6	0·16	0·56

TABLE VI.—ANALYSES OF WATER OF HOL BECK AT JUNCTION WITH AIRE.

Results Expressed in Parts per 100,000.

DATE.	TIME.	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
	During hour commencing at		Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	4. 0 p.m.	—	13·2	108·1	121·3	2·4	2·9	5·3	11·10	—	0·600	0·140	2·14	10·7	15·7	26·4	0·00	0·89
2nd December, 1898	3.30 p.m.	0·5	20·4	103·6	124·0	10·6	15·6	26·2	8·80	Nil	0·365	0·266	4·50	16·0	26·4	42·4	0·06	0·19
3rd March, 1899	3.30 p.m.	0·5	17·0	95·0	112·0	1·4	8·6	10·0	7·90	Nil	0·373	0·110	1·70	11·4	37·1	48·5	0·04	0·06
2nd June, 1899	3.30 p.m.	1·5	20·0	101·2	121·2	4·0	4·0	8·0	9·07	Nil	0·730	0·165	2·07	18·5	27·2	45·7	0·00	0·00
1st September, 1899	3.30 p.m.	1·0	16·4	109·6	126·0	8·4	1·6	10·0	14·60	Nil	0·610	0·160	3·06	21·0	23·0	44·0	0·15	0·80
1st December, 1899	3.30 p.m.	1·5	23·0	112·0	135·0	7·0	2·0	9·0	11·11	Nil	0·500	0·160	3·07	12·5	33·0	45·5	0·00	0·00
2nd March, 1900	3.30 p.m.	2·5	20·0	72·0	92·0	6·0	2·0	8·0	7·60	0·16	0·197	0·123	1·60	6·0	33·0	39·0	0·08	1·33
1st June, 1900	3.30 p.m.	1·5	19·6	122·8	142·4	6·4	5·2	11·6	10·24	Nil	0·560	0·240	3·03	23·0	33·0	56·0	0·00	0·00
7th September, 1900	3.30 p.m.	4·0	13·4	90·8	104·2	0·2	1·8	2·0	10·80	0·02	0·350	0·080	0·82	12·0	30·0	42·0	0·00	0·15
7th December, 1900	3.30 p.m.	2·2	19·2	66·0	85·2	6·8	1·0	7·8	6·44	0·20	0·280	0·134	1·31	6·0	33·0	39·0	0·68	1·36
1st March, 1901	3.30 p.m.	1·0	28·6	86·4	115·0	11·6	12·4	24·0	8·20	Nil	0·440	0·260	2·97	19·0	31·0	50·0	0·28	0·51
7th June, 1901	3.30 p.m.	1·5	28·9	140·5	169·4	10·3	5·5	15·8	10·50	Nil	1·290	0·590	3·44	22·0	34·2	56·2	0·00	0·00
6th September, 1901	3.30 p.m.	1·5	19·0	156·0	175·0	9·0	12·0	21·0	12·00	Nil	1·210	0·260	2·88	26·0	26·0	52·0	0·00	0·00
6th December, 1901	3.30 p.m.	1·5	25·0	108·0	133·0	8·0	1·0	9·0	11·00	Nil	0·850	0·190	2·75	8·5	37·0	45·5	0·00	0·07
7th March, 1902	3.30 p.m.	4·5	16·3	95·5	111·8	2·3	1·5	3·8	9·00	0·12	0·580	0·070	1·32	11·0	33·0	44·0	0·00	0·01
6th June, 1902	3.30 p.m.	3·5	17·7	103·0	120·7	2·2	2·0	4·2	10·00	Nil	1·150	0·080	1·16	6·0	50·0	56·0	0·03	0·88
5th September, 1902	3.30 p.m.	4·5	19·6	106·6	126·2	2·6	1·6	4·2	11·50	Nil	0·750	0·080	1·26	23·2	32·8	56·0	0·00	0·11
5th December, 1902	3.30 p.m.	2·5	18·4	82·6	101·0	4·4	3·6	8·0	8·00	0·44	0·350	0·100	1·60	7·2	40·0	47·2	0·02	1·13
6th March, 1903	3.30 p.m.	2·5	26·8	71·2	98·0	6·8	3·2	10·0	8·00	0·04	0·830	0·230	2·26	7·5	45·7	53·2	0·10	0·45
5th June, 1903	3.30 p.m.	2·0	40·2	122·8	163·0	15·2	2·8	18·0	10·00	Nil	1·510	0·970	1·74	12·5	53·2	65·7	0·00	0·07
4th September, 1903	3.30 p.m.	1·0	108·8	116·6	225·4	91·8	6·6	98·4	11·50	Nil	1·360	0·590	3·84	19·0	31·2	50·2	0·42	0·86
4th December, 1903	3.30 p.m.	1·2	22·6	84·6	107·2	10·6	13·6	24·2	7·50	0·01	0·460	0·220	2·72	4·7	29·7	34·4	0·20	0·57
4th March, 1904	3.30 p.m.	2·2	21·2	86·8	108·0	5·2	3·8	9·0	8·50	0·12	0·440	0·120	2·76	11·0	26·6	37·6	0·10	0·24
3rd June, 1904	3.30 p.m.	2·0	21·0	104·8	125·8	4·0	3·8	7·8	10·00	0·04	0·616	0·100	2·38	11·1	29·7	40·8	0·01	1·28
2nd September, 1904	3.30 p.m.	2·5	20·3	133·0	153·3	2·3	3·0	5·3	12·25	Nil	0·543	0·115	1·63	14·2	26·6	40·8	0·00	0·02
2nd December, 1904	3.30 p.m.	4·2	16·9	85·2	102·1	2·5	2·6	5·1	9·50	0·12	0·585	0·078	1·33	11·0	26·6	37·6	0·01	0·02
AVERAGES:																		
March Samples	—	2.2	21·6	84·5	106·1	5·55	5·25	10·80	8·20	0·07	0·477	0·152	2·10	11·0	34·4	45·4	0·11	0·51
June Samples	—	2·0	24·6	115·8	140·4	7·02	3·88	10·90	10·13	0·01	0·976	0·357	2·30	15·5	38·0	53·5	0·01	0·45
September Samples	—	2·4	30·1	117·2	147·3	16·67	4·22	20·89	11·96	0·002	0·775	0·204	2·23	18·0	26·5	44·5	0·08	0·23
December Samples	—	1·9	20·8	91·7	112·5	7·13	5·62	12·75	8·91	0·11	0·484	0·164	2·33	9·4	32·2	41·6	0·15	0·52
TOTAL SAMPLES	—	2·1	24·4	102·5	126·9	9·31	4·76	14·06	9·85	0·05	0·674	0·217	2·24	13·5	32·5	46·0	0·09	0·43

Mr. H. Maclean Wilson.

16 May 1905.

TABLE VII.—ANALYSES OF WATER OF RIVER CALDER AT HEBDEN BRIDGE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution. Loss on Ignition.	Ash.	Total.	Solids in Suspension only. Loss on Ignition.	Ash.	Total.	Chlorides (as Na Cl).	Nitrogen. Nitric.	Ammoniacal (from Free and Saline Amm.)	Albuminoid (Wanklyn.)	Oxygen absorbed in 4 hours at 80° F.	Hardness. Temp.	Perm.	Total.	Rainfall in ins. at selected stations. During preceding two days.	During preceding week.
2nd September, 1898	11. 0 a.m.	—	4·5	13·7	18·3	—	—	—	2·90	—	0·060	0·040	0·80	2·4	4·3	6·7	0·00	1·21
2nd December, 1898	11. 0 a.m.	2·0	7·6	18·9	26·5	3·7	9·7	13·4	1·64	0·13	0·101	0·066	1·01	Nil	5·3	5·3	0·35	0·43
3rd March, 1899	11. 0 a.m.	5·5	5·4	13·2	18·6	1·3	1·6	2·9	2·90	0·05	0·102	0·041	1·04	0·7	6·0	6·7	0·00	0·00
2nd June, 1899.....	11. 0 a.m	5·0	7·3	9·7	17·0	1·4	0·0	1·4	2·90	0·02	0·058	0·041	0·90	Nil	6·0	6·0	0·00	0·00
1st September, 1899	11. 0 a.m.	5·0	3·8	20·2	24·0	0·2	1·8	2·0	4·39	Nil	0·390	0·050	0·92	3·6	8·2	11·8	0·12	1·01
1st December, 1899	11. 0 a.m.	5·0	6·0	13·9	19·9	1·6	1·1	2·7	2·92	0·05	0·150	0·066	0·76	0·8	6·7	7·5	0·09	0·17
2nd March, 1900	11. 0 a.m.	8·5	6·6	7·6	14·2	0·8	0·8	1·6	2·16	0·08	0·021	0·021	0·40	0·4	5·6	6·0	0·04	1·21
1st June, 1900	11. 0 a.m.	6·5	3·8	15·0	18·8	0·2	1·8	2·0	3·20	Nil	0·122	0·040	0·65	2·0	6·0	8·0	0·00	0·01
7th September, 1900	11. 0 a.m.	9·0	5·0	12·2	17·2	0·2	0·6	0·8	2·92	0·03	0·097	0·033	0·56	0·8	6·7	7·5	0·00	0·32
7th December, 1900	11. 0 a.m.	9·5	4·7	8·7	13·4	1·1	0·7	1·8	2·34	0·06	0·022	0·025	0·38	Nil	6·0	6·0	0·62	1·60
1st March, 1901	11. 0 a.m.	5·0	5·0	9·4	14·4	2·0	2·4	4·4	2·34	0·06	0·057	0·035	0·64	Nil	5·3	5·3	0·58	0·98
14th June, 1901	11. 0 a.m.	6·0	7·8	15·6	23·4	0·8	1·6	2·4	3·60	0·04	0·220	0·070	0·75	Nil	9·0	9·0	0·00	0·25
6th September, 1901	11. 0 a.m.	4·5	8·0	14·0	22·0	2·2	2·8	5·0	3·70	Nil	0·270	0·060	0·90	Nil	8·1	8·1	0·00	0·10
6th December, 1901	11. 0 a.m.	9·5	3·7	13·3	17·0	0·9	0·9	1·8	3·00	0·10	0·100	0·040	0·45	1·0	7·0	8·0	0·08	0·17
7th March, 1902	11. 0 a.m.	9·5	3·6	12·8	16·4	0·4	0·4	0·8	3·20	0·11	0·060	0·035	0·45	1·0	7·0	8·0	0·00	0·00
6th June, 1902	11. 0 a.m.	6·5	4·8	11·7	16·5	0·4	1·7	2·1	3·00	Nil	0·170	0·030	0·49	1·0	6·5	7·5	0·11	0·58
5th September, 1902	11. 0 a.m.	—	4·2	14·2	18·4	1·4	1·4	2·8	3·25	Trace	0·140	0·035	0·51	Nil	7·4	7·4	0·07	0·44
5th December, 1902	11. 0 a.m.	10·5	5·2	13·0	18·2	0·2	1·0	1·2	2·50	0·12	0·033	0·025	0·40	0·7	7·4	8·1	0·01	1·51
6th March, 1903	10.15 a.m.	11·0	3·6	9·5	13·1	0·4	1·1	1·5	2·25	0·10	0·022	0·014	0·36	Nil	8·1	8·1	0·56	1·53
5th June, 1903	11. 0 a.m.	13·5	4·4	14·8	19·2	1·2	0·8	2·0	3·50	Trace	0·108	0·024	0·28	0·7	6·7	7·4	0·00	0·08
4th September, 1903	11. 0 a.m.	11·0	4·2	8·0	12·2	0·6	0·8	1·4	2·25	0·06	0·018	0·018	0·36	0·7	4·6	5·3	0·65	1·80
4th December, 1903	11. 0 a.m.	5·0	3·5	9·3	12·8	0·3	2·1	2·4	2·50	Trace	0·038	0·020	0·50	1·4	4·6	6·0	1·37	1·77
4th March, 1904	11. 0 a.m.	10·5	5·7	10·6	16·3	0·1	0·2	0·3	2·50	0·08	0·030	0·020	0·27	Nil	7·4	7·4	0·24	0·50
3rd June, 1904	11. 0 a.m.	13·0	4·0	11·2	15·2	0·4	0·8	1·2	2·25	0·06	0·035	0·020	0·30	Nil	6·0	6·0	0·00	1·57
2nd September, 1904	11. 0 a.m.	7·0	4·2	11·1	15·3	0·6	1·1	1·7	3·00	0·08	0·100	0·035	0·50	Nil	6·0	6·0	0·02	0·04
2nd December, 1904	11. 0 a.m.	11·0	4·0	10·5	14·5	1·2	1·3	2·5	2·50	0·02	0·040	0·025	0·56	0·4	5·6	6·0	0·07	0·12
AVERAGES :																		
March Samples	—	8·3	5·0	10·5	15·5	0·8	1·1	1·9	2·56	0·08	0·048	0·027	0·53	0·3	6·6	6·9	0·23	0·70
June Samples	—	8·4	5·3	13·0	18·3	0·7	1·1	1·8	3·07	0·02	0·119	0·037	0·50	0·6	6·7	7·3	0·02	0·41
September Samples ..	—	7·3	4·8	13·4	18·2	0·7	1·2	1·9	3·20	0·02	0·153	0·033	0·65	1·1	6·5	7·6	0·12	0·70
December Samples ..	—	7·5	5·0	12·5	17·5	1·3	2·4	3·7	2·48	0·07	0·069	0·038	0·44	0·6	6·1	6·7	0·37	0·82
TOTAL SAMPLES.....	—	7·9	5·0	12·3	17·3	0·9	1·5	2·4	2·86	0·05	0·097	0·036	0·57	0·7	6·4	7·1	0·19	0·67

TABLE VIII.—ANALYSES OF WATER OF RIVER CALDER AT COOPER BRIDGE

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution. Loss on Ignition.	Ash.	Total.	Solids in Suspension only. Loss on Ignition.	Ash.	Total.	Chlorides (as Na Cl).	Nitrogen. Nitric.	Ammoniacal (from Free and Saline Amm.)	Albuminoid (Wanklyn.)	Oxygen absorbed in 4 hours at 80° F.	Hardness. Temp.	Perm.	Total.	Rainfall in ins. at selected stations. During preceding two days.	During preceding week.
2nd September, 1898	10.50 a.m.	—	5·8	19·1	24·9	—	—	—	4·08	—	0·164	0·042	0·63	0·7	6·7	7·4	0·00	0·89
2nd December, 1898	11. 0 a.m.	2·0	5·4	20·0	25·4	0·2	6·2	6·2	2·30	0·26	0·155	0·049	0·76	0·7	6·7	7·4	0·06	0·19
3rd March, 1899	11. 0 a.m.	5·5	7·5	24·0	31·5	1·2	0·9	4·1	4·40	0·07	0·258	0·066	0·80	3·5	8·4	11·7	0·04	0·06
2nd June, 1899.....	11. 0 a.m.	6·0	—	—	28·3	—	—	4·1	4·38	0·03	0·223	0·060	0·60	2·9	7·4	10·3	0·00	0·00
1st September, 1899	11. 0 a.m.	5·0	6·4	32·8	39·2	2·0	2·0	2·0	5·56	Nil	0·620	0·120	1·13	0·7	13·3	14·0	0·15	0·80
1st December, 1899	11. 0 a.m.	5·0	7·4	23·0	30·4	0·5	1·2	1·7	4·68	0·05	0·280	0·069	0·66	2·0	9·0	11·0	0·00	0·00
2nd March, 1900	11. 0 a.m.	8·5	6·4	15·0	21·4	1·6	0·8	4·2	2·92	0·21	0·046	0·036	0·32	Nil	9·0	9·0	0·08	1·33
1st June, 1900	10.35 a.m.	5·5	5·0	29·4	34·4	0·2	1·4	1·6	5·26	Nil	0·560	0·075	0·67	3·0	9·5	12·5	0·00	0·00
7th September, 1900	10.50 a.m.	6·5	6·5	24·1	30·6	0·2	0·7	0·9	4·68	0·02	0·290	0·080	0·54	0·5	11·5	12·0	0·00	0·15
7th December, 1900	10.50 a.m.	9·0	4·6	15·6	20·2	0·6	2·0	2·6	2·65	0·12	0·033	0·031	0·34	Nil	9·0	9·0	0·68	1·36
1st March, 1901	10.40 a.m.	2·5	10·8	18·2	29·0	2·8	7·2	10·0	3·04	0·10	0·114	0·070	0·95	Nil	6·7	6·7	0·28	0·51
7th June, 1901	10.50 a.m.	4·0	8·0	30·0	38·0	3·6	2·0	5·6	5·20	Nil	0·670	0·210	1·02	0·3	12·2	12·5	0·00	0·00
6th September, 1901	10.50 a.m.	3·5	10·0	28·0	38·0	2·4	1·6	4·0	6·20	Nil	0·650	0·110	0·90	Nil	13·5	13·5	0·00	0·00
6th December, 1901	10.50 a.m.	7·0	6·4	22·1	28·5	2·4	1·6	4·0	4·20	0·13	0·255	0·053	0·55	1·0	9·5	10·5	0·00	0·07
7th March, 1902	10.30 a.m.	8·0	8·0	21·2	29·2	1·2	·8	2·0	4·30	0·09	0·270	0·056	0·55	2·5	10·5	13·0	0·00	0·01
6th June, 1902	10.50 a.m.	6·5	5·5	24·7	30·2	0·7	1·1	1·8	5·00	Nil	0·420	0·045	0·53	3·0	9·0	12·0	0·03	0·88
5th September, 1902	11. 0 a.m.	6·5	7·2	25·6	32·8	1·2	1·6	2·8	5·50	Nil	0·520	0·070	0·78	1·5	10·3	11·8	0·00	0·11
5th December, 1902	10.40 a.m.	11·0	7·1	18·9	26·0	1·1	0·9	2·0	4·00	0·22	0·095	0·050	0·55	0·7	10·3	11·0	0·02	1·13
6th March, 1903	10.45 a.m.	10·5	5·1	14·7	19·8	0·7	0·7	1·4	3·00	0·22	0·055	0·026	0·48	0·7	9·6	10·3	0·10	0·45
5th June, 1903	10.45 a.m.	7·0	6·8	24·4	31·2	2·0	1·6	3·6	5·00	Trace	0·464	0·035	0·40	Nil	11·0	11·0	0·00	0·07
4th September, 1903	10.45 a.m.	10·0	5·6	15·4	21·0	1·6	1·4	3·0	2·75	0·10	0·077	0·037	0·49	0·7	6·0	6·7	0·42	0·86
4th December, 1903	10.45 a.m.	4·7	4·5	14·5	19·0	1·3	4·1	5·4	2·50	0·10	0·050	0·036	0·70	0·7	6·0	6·7	0·20	0·57
4th March, 1904	10.30 a.m.	5·5	6·4	22·4	28·8	0·0	1·6	1·6	4·00	0·16	0·180	0·040	0·41	0·8	11·0	11·8	0·10	0·24
3rd June, 1904	10.45 a.m.	8·0	5·3	19·8	25·1	0·9	1·0	1·9	3·50	0·07	0·199	0·050	0·64	Nil	8·1	8·1	0·01	1·28
2nd September, 1904	10.50 a.m.	5·5	6·0	23·0	29·0	0·8	1·0	1·8	5·50	0·06	0·215	0·042	0·60	0·7	8·9	9·6	0·00	0·02
2nd December, 1904	10.40 a.m.	10·0	6·2	19·4	25·6	2·2	1·4	3·6	3·50	0·10	0·170	0·068	0·69	Nil	7·4	7·4	0·01	0·02
AVERAGES:																		
March Samples	—	6·7	7·4	19·3	26·7	1·2	2·0	3·2	3·61	0·14	0·154	0·049	0·58	1·2	9·2	10·4	0·10	0·43
June Samples	—	6·1	6·1	25·1	31·2	1·4	1·4	2·8	2·72	0·03	0·423	0·079	0·48	1·5	9·5	11·0	0·01	0·37
September Samples ..	—	6·1	6·8	24·0	30·8	1·2	1·2	2·4	4·89	0·02	0·362	0·071	0·72	0·7	10·0	10·7	0·05	0·35
December Samples ..	—	7·0	6·0	19·1	25·1	1·2	2·5	3·7	3·40	0·14	0·148	0·051	0·62	0·7	8·3	9·0	0·14	0·46
TOTAL SAMPLES ...	—	**6·4**	**6·5**	**21·8**	**28·3**	**1·2**	**1·8**	**3·0**	**4·15**	**0·08**	**0·270**	**0·062**	**0·67**	**1·0**	**9·3**	**10·3**	**0·07**	**0·40**

TABLE IX.—ANALYSES OF WATER OF RIVER CALDER AT THORNES.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	11 to 11.40	—	5·8	32·6	38·4	—	—	—	7·00	—	0·170	0·060	0·98	1·4	7·4	8·8	0·00	0·89
2nd December, 1898	11. 0 a.m.	11·0	5·7	20·8	26·5	0·8	0·9	1·7	4·44	0·28	0·158	0·050	0·67	1·6	7·7	9·3	0·06	0·19
3rd March, 1899	11. 0 a.m.	4·0	9·5	41·7	51·2	2·3	0·9	3·2	9·60	0·09	0·330	0·090	1·10	6·2	11·8	18·0	0·04	0·06
2nd June, 1899.....	10.45 a.m.	6·5	—	—	43·3	—	—	3·5	8·60	0·04	0·250	0·059	0·70	3·7	10·3	14·0	0·00	0·00
1st September, 1899	10.45 a.m.	4·0	7·2	49·2	56·4	1·2	2·0	3·2	10·53	Nil	0·720	0·074	0·96	5·5	14·0	19·5	0·15	0·80
1st December, 1899	10.45 a.m.	5·0	8·0	38·4	46·4	0·4	1·2	1·7	8·48	0·04	0·350	0·090	0·90	3·7	10·3	14·0	0·00	0·00
2nd March, 1900	10.45 a.m.	4·5	11·2	24·8	36·0	3·2	0·8	4·0	4·38	0·23	0·078	0·058	0·61	1·5	12·0	13·5	0·08	1·33
1st June, 1900	10.45 a.m.	7·0	6·4	49·6	56·0	0·6	2·0	2·6	11·11	Nil	0·577	0·058	0·68	4·0	14·8	18·8	0·00	0·00
7th September, 1900	10.45 a.m.	7·0	8·9	35·7	44·6	0·9	0·3	1·2	8·48	0·02	0·390	0·066	0·64	1·0	14·0	15·0	0·00	0·15
7th December, 1900	10.40 a.m.	7·0	4·9	22·3	27·2	1·3	3·1	4·4	3·51	0·20	0·055	0·038	0·48	0·0	12·0	12·0	0·68	1·36
1st March, 1901	10.40 a.m.	2·5	12·2	27·6	39·8	5·2	5·6	10·8	4·68	0·04	0·290	0·157	1·06	2·0	10·5	12·5	0·28	0·51
7th June, 1901	10.40 a.m.	4·5	8·8	48·4	57·2	2·4	2·0	4·4	11·00	Nil	0·730	0·140	0·90	2·0	16·0	18·0	0·00	0·00
6th September, 1901	10.40 a.m.	4·0	7·0	51·0	58·0	1·6	2·0	3·6	12·00	Nil	0·660	0·070	0·77	2·0	14·5	16·5	0·00	0·00
6th December, 1901	10.40 a.m.	4·0	9·4	34·0	43·4	2·4	2·0	4·4	8·40	0·15	0·380	0·087	1·01	·5	15·0	15·5	0·00	0·07
7th March, 1902	10.40 a.m.	5·5	7·6	36·4	44·0	1·6	2·4	4·0	7·30	0·14	0·310	0·095	0·87	2·5	12·5	15·0	0·00	0·01
6th June, 1902	10.40 a.m.	6·5	6·6	40·5	47·1	1·4	2·1	3·5	8·20	Nil	0·500	0·066	0·72	2·5	14·0	16·5	0·03	0·88
5th September, 1902	10.40 a.m.	5·0	8·0	39·8	47·8	2·0	2·8	4·8	8·50	Nil	0·710	0·075	0·99	2·0	13·6	15·6	0·00	0·11
5th December, 1902	10.30 a.m.	7·0	6·5	29·8	36·3	1·5	1·8	3·3	5·00	0·20	0·130	0·054	0·80	1·2	13·6	14·8	0·02	1·13
6th March, 1903	10.30 a.m.	5·0	8·7	34·1	42·8	1·9	2·5	4·4	2·75	0·17	0·070	0·043	0·76	2·3	11·0	13·3	0·10	0·45
5th June, 1903	10.30 a.m.	9·5	10·0	38·4	48·4	2·4	1·6	4·0	8·00	Trace	0·535	0·050	0·35	0·8	14·8	15·6	0·00	0·07
4th September, 1903	10.30 a.m.	7·5	5·6	20·8	26·4	1·2	1·6	2·8	4·25	0·09	0·117	0·045	0·67	0·7	6·7	7·4	0·42	0·86
4th December, 1903	10.30 a.m.	2·5	7·1	20·6	27·7	2·6	8·6	11·2	3·00	0·11	0·070	0·040	0·96	0·7	6·7	7·4	0·20	0·57
4th March, 1904	10.30 a.m.	5·5	7·6	36·0	43·6	0·0	2·0	2·0	6·50	0·14	0·270	0·045	0·86	1·5	14·1	15·6	0·10	0·24
3rd June, 1904	10.30 a.m.	4·0	6·9	31·7	38·6	2·1	2·1	4·2	6·50	Trace	0·220	0·066	1·02	1·5	10·3	11·8	0·01	1·28
2nd September, 1904	10.30 a.m.	5·0	7·4	38·3	45·7	1·9	1·1	2·1	8·50	0·07	0·336	0·055	0·69	3·0	10·3	13·3	0·00	0·02
2nd December, 1904	10.30 a.m.	6·0	8·3	30·2	38·5	2·3	2·2	4·5	6·00	0·04	0·267	0·067	0·98	0·7	9·6	10·3	0·01	0·02
AVERAGES:																		
March Samples	—	4·5	9·5	33·4	42·9	2·4	2·4	4·8	5·87	0·13	0·225	0·081	0·88	2·7	11·9	14·6	0·10	0·43
June Samples	—	6·3	7·5	40·9	48·4	1·7	2·0	3·7	8·90	0·01	0·470	0·073	0·56	2·4	13·4	15·8	0·01	0·37
September Samples ..	—	5·5	7·1	38·2	45·3	1·1	1·4	2·5	9·46	0·02	0·443	0·064	0·81	2·2	11·5	13·7	0·05	0·35
December Samples ..	—	6·0	7·1	28·0	35·1	1·6	2·8	4·4	5·55	0·14	0·201	0·061	0·83	1·2	10·7	11·9	0·14	0·46
TOTAL SAMPLES	—	5·5	7·8	35·1	42·9	1·7	2·1	3·8	7·30	0·08	0·340	0·069	0·77	2·1	11·9	14·0	0·07	0·40

TABLE X.—ANALYSES OF WATER OF RIVER CALDER AT JUNCTION WITH AIRE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	10.30 a.m.	—	7·3	33·0	40·3	—	—	—	10·50	—	0·235	0·070	0·78	3·7	8·1	11·8	0·00	0·89
2nd December, 1898	12 Noon	7·5	5·9	28·1	34·0	1·4	0·7	2·1	7·03	0·31	0·190	0·041	0·53	1·8	10·0	11·8	0·06	0·19
3rd March, 1899	10. 0 a.m.	6·5	9·3	44·3	53·6	1·3	1·3	2·6	12·00	0·12	0·300	0·063	0·65	5·3	14·3	19·6	0·04	0·06
2nd June, 1899	10.30 a.m.	7·5	7·2	38·8	46·0	1·6	1·9	3·5	8·20	—	0·240	0·050	0·60	4·5	10·3	14·8	0·00	0·00
1st September, 1899	10.15 a.m.	4·5	6·2	68·6	74·8	0·6	0·2	0·8	25·45	Nil	0·890	0·060	0·80	9·7	13·3	23·0	0·15	0·80
1st December, 1899	10.20 a.m.	7·5	8·0	44·3	52·3	1·6	0·3	1·9	14·04	0·03	0·543	0·090	0·62	0·5	15·0	15·5	0·00	0·00
2nd March, 1900	10. 0 a.m.	5·5	5·2	29·6	34·8	0·6	1·0	1·6	5·55	0·38	0·048	0·030	0·46	1·5	13·5	15·0	0·08	1·33
1st June, 1900	10. 0 a.m.	6·5	6·6	57·0	63·6	0·8	0·4	1·2	19·89	Nil	0·057	0·047	0·62	2·4	16·4	18·8	0·00	0·00
7th September, 1900	10. 0 a.m.	7·0	8·7	39·5	48·2	0·6	0·2	0·8	11·10	0·03	0·395	0·049	0·44	2·5	15·5	18·0	0·00	0·15
7th December, 1900	10.20 a.m.	4·0	9·5	30·3	39·8	3·9	5·9	9·8	6·14	0·12	0·058	0·058	0·84	1·5	12·5	14·0	0·68	1·36
1st March, 1901	10.30 a.m.	5·0	13·8	32·6	46·4	4·8	3·6	8·4	8·77	0·06	0·266	0·069	0·57	2·0	13·5	15·5	0·28	0·51
7th June, 1901	10.30 a.m.	9·0	9·6	56·8	66·4	1·6	0·8	2·4	17·00	Nil	0·830	0·100	0·50	1·0	21·0	22·0	0·00	0·00
6th September 1901	10.30 a.m.	7·5	11·0	59·0	70·0	0·8	1·2	2·0	18·50	Trace	0·410	0·050	0·53	5·0	14·0	19·0	0·00	0·00
6th December, 1901	10.15 a.m.	6·0	8·6	35·2	43·8	1·6	1·2	2·8	10·50	0·15	0·330	0·057	0·53	1·5	15·5	17·0	0·00	0·07
7th March, 1902	10.15 a.m.	7·5	8·0	38·2	46·2	1·0	1·2	2·2	10·00	0·18	0·280	0·050	0·51	5·5	12·0	17·5	0·00	0·01
6th June, 1902	10.30 a.m.	6·5	6·0	41·2	47·2	0·4	1·2	1·6	11·20	0·08	0·130	0·045	0·50	1·5	16·5	18·0	0·03	0·88
5th September, 1902	10.30 a.m.	12·5	11·2	43·0	54·2	0·2	1·0	1·2	14·70	0·06	0·490	0·045	0·46	0·0	16·4	16·4	0·00	0·11
5th December, 1902	10.30 a.m.	7·0	6·4	32·6	39·0	0·4	1·6	2·0	8·40	0·24	0·133	0·043	0·62	1·6	15·6	17·2	0·02	1·13
6th March, 1903	10.30 a.m.	5·5	6·4	23·2	29·6	1·4	2·8	4·2	5·00	0·21	0·068	0·036	0·64	1·7	12·6	13·3	0·10	0·45
5th June, 1903	10.30 a.m.	8·0	10·2	50·4	60·6	1·4	4·4	5·8	12·25	Trace	0·454	0·048	0·42	4·4	14·8	19·2	0·00	0·07
4th September, 1903	10.30 a.m.	6·5	6·2	21·6	27·8	1·4	2·8	4·2	5·75	0·08	0·121	0·036	0·72	0·7	7·4	8·1	0·42	0·86
4th December, 1903	10.30 a.m.	2·2	9·4	26·8	36·2	4·4	8·8	13·2	4·50	0·09	0·140	0·070	1·28	2·2	8·1	10·3	0·20	0·57
4th March, 1904	10.30 a.m.	7·0	8·0	40·0	48·0	0·4	1·2	1·6	9·00	0·18	0·210	0·040	0·72	3·1	14·1	17·2	0·10	0·24
3rd June, 1904	10.30 a.m.	5·5	5·5	33·4	38·9	0·9	1·5	2·4	8·00	0·07	0·265	0·044	0·61	0·8	11·0	11·8	0·01	1·28
2nd September, 1904	10.30 a.m.	5·5	5·2	39·8	45·0	0·4	1·8	2·2	11·50	Trace	0·313	0·040	0·47	2·3	11·8	14·1	0·00	0·02
2nd December, 1904	10.30 a.m.	6·5	11·6	36·7	48·3	2·6	1·7	4·3	9·75	0·03	0·442	0·075	1·05	1·5	11·8	13·3	0·01	0·02
AVERAGES:																		
March Samples	—	6·1	8·5	34·6	43·1	1·6	1·8	3·4	7·19	0·16	0·171	0·042	0·51	3·0	13·3	16·3	0·10	0·43
June Samples	—	7·1	7·5	46·3	53·8	1·1	1·7	2·8	12·76	0·02	0·329	0·056	0·54	2·4	15·0	17·4	0·01	0·37
September Samples	—	7·2	8·0	43·5	51·5	0·6	1·0	1·6	13·90	0·02	0·407	0·050	0·60	3·4	12·4	15·8	0·05	0·35
December Samples	—	5·8	8·5	33·4	41·9	2·3	2·9	5·2	8·62	0·14	0·262	0·062	0·78	1·6	12·7	14·3	0·14	0·46
TOTAL SAMPLES ..	—	6·2	8·1	39·4	47·5	1·4	1·9	3·3	10·90	0·09	0·260	0·062	0·64	2·6	13·3	15·9	0·07	0·40

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Mr. H. Madeau Wilson. 16 May 1905.

TABLE XI.—ANALYSES OF WATER OF RIVER COLNE AT JUNCTION WITH CALDER.

Results Expressed in Parts per 100,000.

DATE.	TIME.	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
	During hour commencing at		Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
1st December, 1899	9.45 a.m.	5·0	7·6	34·2	41·8	0·6	1·7	2·3	7·02	0·06	0·255	0·074	1·01	2·0	10·5	12·5	0·00	0·00
2nd March, 1900	9.30 a.m.	4·0	6·8	20·8	27·6	1·60	2·0	3·6	4·39	0·50	0·050	0·046	0·59	Nil	10·3	10·3	0·08	1·33
1st June, 1900	9.20 a.m.	4·5	7·2	37·2	44·4	4·0	2·0	6·0	7·43	Nil	0·304	0·080	1·00	3·0	10·3	13·3	0·00	0·00
7th September, 1900	9.30 a.m.	3·5	7·8	34·8	42·6	1·3	2·2	3·5	7·30	Nil	0·365	0·093	1·00	4·0	9·3	13·3	0·00	0·15
7th December, 1900	9.30 a.m.	7·0	6·5	18·3	24·8	1·9	1·9	3·8	3·63	0·21	0·026	0·026	0·45	Nil	10·3	10·3	0·68	1·36
1st March, 1901	9.20 a.m.	2·5	6·8	21·2	28·0	·8	5·2	6·0	3·80	0·08	0·130	0·073	0·98	1·5	9·5	11·0	0·28	0·51
7th June, 1901	9.30 a.m.	3·0	7·2	39·6	46·8	1·6	3·6	5·2	7·50	Nil	0·460	0·170	1·10	1·3	12·0	13·3	0·00	0·00
6th September, 1901	9.30 a.m.	3·0	13·0	44·0	57·0	4·0	4·4	8·4	10·50	Nil	0·460	0·160	1·76	2·0	12·0	14·0	0·00	0·00
6th December, 1901	9.25 a.m.	3·5	7·5	33·0	40·5	2·0	2·0	4·0	5·70	0·11	0·250	0·070	0·88	1·5	13·0	14·5	0·00	0·07
7th March, 1902	9.20 a.m.	3·5	8·0	30·4	38·4	2·0	2·4	4·4	6·50	0·16	0·280	0·073	1·28	1·5	13·0	14·5	0·00	0·01
6th June, 1902	9.30 a.m.	3·0	7·6	36·0	43·6	3·6	4·0	7·6	6·00	Nil	0·260	0·120	1·44	3·5	10·0	13·5	0·03	0·88
5th September, 1902	10.20 a.m.	2·0	10·5	41·6	52·1	6·1	6·4	12·5	6·80	Nil	0·400	0·220	2·16	3·0	10·3	13·3	0·00	0·11
5th December, 1902	9.25 a.m.	5·5	6·7	22·3	29·0	1·4	1·7	3·1	4·40	0·30	0·060	0·058	0·80	0·8	11·0	11·8	0·02	0·13
6th March, 1903	9.25 a.m.	6·0	6·0	17·6	23·6	1·2	1·2	2·4	3·75	0·24	0·048	0·036	0·66	1·1	12·2	13·3	0·10	0·45
5th June, 1903	9.20 a.m.	5·0	7·0	35·8	42·8	1·6	1·2	2·8	6·25	Nil	0·305	0·075	0·81	2·3	13·3	15·6	0·00	0·07
4th September, 1903	9.20 a.m.	7·0	7·0	22·3	29·3	2·0	2·8	4·8	4·50	0·15	0·063	0·041	0·70	1·2	9·1	10·3	0·42	0·86
4th December, 1903	9.20 a.m.	4·0	4·8	20·5	25·3	1·9	4·2	6·1	3·00	0·13	0·053	0·048	0·80	Nil	6·7	6·7	0·20	0·57
4th March, 1904	8.30 a.m.	3·5	8·2	30·4	38·6	2·2	1·6	3·8	6·00	0·22	0·202	0·045	1·06	3·0	11·8	14·8	0·10	0·24
3rd June, 1904	9 25 am.	4·0	10·0	28·5	38·5	4·0	4·5	8·5	5·00	0·08	0·095	0·090	1·24	0·7	9·6	10·3	0·01	0·28
2nd September, 1904	9.30 a.m.	5·5	5·3	31·7	37·0	0·5	1·5	4·0	5·25	0·07	0·168	0·046	0·84	0·7	10·3	11·0	0·00	0·02
2nd December, 1904	9.20 a.m.	3·5	7·8	28·2	36·0	3·2	2·2	5·2	5·00	0·05	0·166	0·065	1·12	2·2	9·6	11·8	0·01	0·02
AVERAGES:																		
March Samples	—	3·9	7·1	24·1	31·2	1·5	2·5	4·0	4·88	0·24	0·142	0·052	0·91	1·4	11·4	12·8	0·11	0·51
June Samples	—	3·9	7·8	35·4	43·2	3·0	3·0	6·0	6·43	0·02	0·285	0·107	1·12	2·2	11·0	13·2	0·01	0·45
September Samples ..	—	4·2	8·7	34·9	43·6	2·8	3·4	6·2	6·87	0·04	0·291	0·112	1·29	2·2	10·2	12·4	0·08	0·23
December Samples ..	—	4·7	6·8	26·1	32·9	1·8	2·3	4·1	4·79	0·10	0·135	0·057	0·84	1·1	10·2	11·3	0·15	0·52
TOTAL SAMPLES	—	**4·2**	**7·6**	**29·9**	**37·5**	**2·2**	**2·8**	**5·0**	**5·70**	**0·11**	**0·210**	**0·081**	**1·03**	**1·7**	**10·7**	**12·4**	**0·09**	**0·43**

TABLE XII.—ANALYSES OF WATER OF DEWSBURY BECK AT JUNCTION WITH CALDER.

Results expressed in parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	3.15 p.m.	—	89·5	132·8	222·3	71·1	33·7	104·8	21·00	—	0·530	0·860	12·17	5·4	15·7	21·1	0·00	0·89
2nd December, 1898	3. 0 p.m.	0·5	25·8	115·8	141·6	10·2	42·4	52·6	9·95	Nil	0·660	0·370	6·60	3 5	24·3	27·8	0·06	0·19
3rd March, 1899	3. 0 p.m.	0·5	36·0	107·4	143·4	17·4	1·0	18·4	13·76	Nil	0·660	0·430	7·30	10·0	30·0	40·0	0·04	0·06
2nd June, 1899	3. 0 p.m.	1·0	50·4	119·6	170·0	23·2	15·2	38·4	18·80	Nil	0·540	0·470	10·80	12·3	23·7	36·0	0·00	0·00
1st September, 1899	3. 0 p.m.	1·0	29·0	102·0	131·0	13·0	11·0	24·0	16·40	Nil	0·570	0·450	6·94	10·5	20·5	31·0	0·15	0·80
1st December, 1899	3.45 p.m.	1·0	30·0	104·0	134·0	10·0	14·2	24·2	14·04	Nil	1·090	0·480	7·00	12·0	24·0	36·0	0·00	0·00
2nd March, 1900	3.30 p.m.	1·0	33·0	89·0	122·0	19·0	7·0	26·0	9·95	Nil	0·210	0·370	5·05	10·0	36·0	46·0	0·08	1·33
1st June, 1900	3.40 p.m.	1·0	39·0	110·0	149·0	24·6	13·4	38·0	18·13	Nil	0·749	0·700	7·44	11·0	26·6	37·6	0·00	0·00
7th September, 1900	3 30 p.m.	1·0	43·6	106·0	149·6	29·8	11·0	40·8	15·80	Nil	0·550	0·920	8·06	9·5	23·5	33·0	0·00	0·15
7th December, 1900	3.30 p.m.	1·0	34·0	78·6	112·6	18·4	8·0	26·4	8·48	Nil	0·220	0·350	3·79	3·0	33·0	36·0	0·68	1·36
1st March, 1901	3.20 p.m.	1·0	37·2	108·0	145·2	21·2	16·0	37·2	12·90	Nil	0·670	0·430	6·64	9·0	33·0	42·0	0·28	0·51
7th June, 1901	3.40 p.m.	1·0	66·4	105·0	171·4	52·4	12·0	64·4	18·50	Nil	0·840	0·730	8·90	8·5	21·2	29·7	0·00	0·00
6th September, 1901	2.40 p.m.	1·0	41·0	138·0	179·0	31·0	13·6	44·6	22·00	Nil	0·900	0·960	9·78	6·5	28·0	34·5	0·00	0·00
6th December, 1901	3.15 p.m.	1·0	28·0	115·6	143·6	17·0	12·0	29·0	16·20	Nil	0·880	0·460	6·72	21·0	16·5	37·5	0·00	0·07
7th March, 1902	3.20 p.m.	1·0	42·0	101·0	143·0	27·0	11·0	38·0	12·50	Nil	0·610	0·440	6·64	9·5	26·5	36·0	0·00	0·01
6th June, 1902	3. 0 p.m.	1·0	27·2	112·0	139·2	16·2	8·0	24·2	13·50	Nil	0·800	0·420	5·30	Nil	31·0	31·0	0·03	0·88
5th September, 1902	3. 0 p.m.	1·0	193·0	170·0	363·0	182·0	79·0	261·0	15·50	Nil	0·730	1·770	24·60	20·4	17·2	37·6	0·00	0·11
5th December, 1902	3. 0 p.m.	1·0	31·0	85·2	116·2	16·0	7·2	23·2	11·40	Nil	0·430	0·360	4·56	3·2	32·8	36·0	0·02	1·13
6th March, 1903	3. 0 p.m.	1·5	26·0	75·0	101·0	15·0	5·0	20·0	11·10	·24	0·360	0·450	4·84	3·2	40·8	44·0	0·10	0·45
5th June, 1903	3. 0 p.m.	0·7	39·4	112·0	151·4	24·4	8·0	32·4	16·00	Nil	1·560	0·520	6·50	1·6	37·6	39·2	0·00	0·07
4th September, 1903	3. 0 p.m.	1·0	37·2	102·2	139·4	22·4	6·6	29·0	13·00	Nil	0·540	0·328	4·92	9·2	23·6	32·8	0·42	0·86
4th December, 1903	2.40 p.m.	0·5	107·0	90·0	197·0	89·0	12·0	101·0	9·50	Nil	0·444	0·280	3·44	9·2	23·6	32·8	0·20	0·57
4th March, 1904	3. 0 p.m.	0·5	37·0	107·0	144·0	18·0	15·0	33·0	11·50	Trace	0·700	0·340	7·08	3·1	26·6	29·7	0·10	0·24
3rd June, 1904	2.50 p.m.	0·5	30·4	110·8	141·2	15·4	7·8	23·2	11·50	Nil	0·572	0·308	6·46	14·1	25·1	39·2	0·01	1·28
2nd September, 1904	2.45 p.m.	0·5	51·6	134·4	186·0	30·6	15·4	46·0	16·50	Nil	0·612	0·632	9·40	7·8	25·1	32·9	0·00	0·02
2nd December, 1904	2.40 p.m.	0·5	41·3	103·7	145·0	20·3	7·7	28·0	13·00	Nil	0·930	0·561	8·28	12·2	19·1	31·3	0·01	0·02
AVERAGES:																		
March Samples	—	0·9	35·2	97·9	133·1	19·60	9·17	28·77	11·95	0·04	0·535	0·410	6·26	7·5	32·1	39·6	0·10	0·43
June Samples	—	0·9	42·1	111·6	153·7	26·03	10·73	36·76	16·07	Nil	0·677	0·525	7·57	7·9	27·5	35·4	0·01	0·37
September Samples	—	0·9	69·3	126·5	195·8	54·27	24·33	78·60	17·17	Nil	0·633	0·846	10·84	9·9	21·9	31·8	0·08	0·40
December Samples	—	0·8	42·4	99·0	141·4	25·84	14·79	40·63	11·79	Nil	0·665	0·409	5·77	9·1	24·8	33·9	0·14	0·48
TOTAL SAMPLES	—	0·9	47·9	109·0	156·9	32·10	15·10	47·20	14·27	0·01	0·629	0·553	7·66	8·7	26·3	35·0	0·08	0·42

Mr. H. Maclean's Wilson. 16 May 1905.

TABLE XIII.—ANALSYSES OF WATER OF HEBBLE BROOK AT JUNCTION WITH CALDER.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	2.15 p.m.	—	24·4	58·8	83·2	13·2	9·2	22·4	12·30	—	1·500	0·400	5·07	7·6	8·8	16·4	0·00	1·21
2nd December, 1898	2. 0 p.m	0·5	22·8	55·0	77·8	17·6	23·8	41·4	9·07	Nil	0·540	0·270	2·80	3·9	13·5	16·4	0·35	0·43
3rd March, 1899	2. 0 p.m	0·5	31·8	49·2	81·0	14·8	2·2	17·0	10·86	Nil	1·750	0·560	5·10	4·7	12·3	18·0	0·00	0·00
2nd June, 1899.....	2.15 p.m.	1·0	32·2	65·8	98·0	20·0	11·0	31·0	12·90	Nil	2·360	0·490	7·40	5·0	9·3	14·3	0·00	0·00
1st September, 1899	2. 0 p.m.	1·0	35·0	66·0	101·0	18·0	14·0	32·0	12·60	Nil	2·090	0·799	7·85	11·0	9·5	20·5	0·12	1·01
1st December, 1899	2. 0 p.m.	1·0	45·0	114·0	159·0	31·0	73·2	104·2	11·11	Nil	1·850	0·790	7·80	7·5	13·5	21·0	0·09	0·17
2nd March, 1900	2. 0 p.m.	1·5	17·4	34·0	51·4	5·4	7·0	12·4	5·85	Nil	0·870	0·280	2·37	4·0	11·0	15·0	0·04	1·21
1st June, 1900	2. 0 p.m.	1·0	41·4	66·6	108·0	33·4	2·6	36·0	15·21	Nil	2·500	0·890	7·90	12·0	12·0	24·0	0·00	0·01
7th September, 1900	2. 0 p.m.	1·0	42·0	74·0	116·2	26·8	20·2	47·0	14·90	Nil	3·450	0·790	6·86	9·0	7·5	16·5	0·00	0·32
7th December, 1900	2. 0 p.m.	1·0	22·4	44·0	66·4	11·4	12·4	23·8	5·85	Nil	0·260	0·400	2·90	3·0	12·0	15·0	0·62	1·60
1st March, 1901.....	2. 0 p.m.	1·0	19·8	40·8	60·6	10·8	12·8	23·6	5·85	Nil	0·980	0·280	3·00	5·5	9·5	15·0	0·58	0·98
14th June, 1901	2. 0 p.m.	1·0	41·0	65·4	106·4	23·0	8·4	31·4	13·00	Nil	1·920	0·950	6·60	5·0	14·5	19·5	0·00	0·25
6th September, 1901	2. 0 p.m.	1·0	24·0	62·0	86·0	18·4	6·6	25·0	13·00	Nil	2·250	0·590	7·14	5·0	12·0	17·0	0·00	0·10
6th December, 1901	2. 0 p.m.	1·0	29·0	52·0	81·0	15·0	6·0	21·0	12·00	Nil	2·900	0·540	6·44	7·5	12·0	19·5	0·08	0·17
7th March, 1902	2. 0 p.m.	1·0	36·0	34·0	70·0	17·0	3·0	20·0	9·20	Nil	2·110	0·870	4·63	11·0	8·0	19·0	0·00	0·00
6th June, 1902	2. 0 p.m.	1·0	37·0	76·5	113·5	26·0	13·0	39·0	16·00	Nil	2·900	1·200	8·90	10·0	16·0	26·0	0·11	0·58
5th September, 1902	2. 0 p.m.	1·0	34·0	60·0	94·0	23·0	7·0	30·0	12·80	Nil	3·450	0·620	6·44	7·7	10·3	18·0	0·07	0·44
5th December, 1902	2. 0 p.m.	1·0	29·2	53·2	82·4	16·2	7·2	23·4	10·00	Nil	1·780	0·500	6·10	3·2	18·8	22·0	0·01	1·51
6th March, 1903	12.45 p.m.	1·5	21·6	42·4	64·0	11·6	5·4	17.0	7.25	0·12	1·020	0·330	3·65	0·8	16·4	17·2	0·56	1·53
5th June, 1903	2.15 p.m.	0·5	46·0	87·0	133·0	37·0	25·0	62·0	14·75	Nil	3·850	0·820	8·34	1·6	16·4	18·0	0·00	0·08
4th September, 1903	2. 0 p.m.	1·0	38·0	60·0	98·0	21·0	9·0	30·0	10·50	Nil	2·320	0·450	8·16	5·5	12·5	18·0	0·65	1·80
4th December, 1903	2. 0 p.m.	1·5	14·0	36·5	50·5	6·0	10·5	16·5	5·50	Nil	0·889	0·240	2·88	2·9	12·0	14·9	1·37	1·77
4th March, 1904	2. 0 p.m.	1·5	18·0	50·0	68·0	6·0	5·0	11·0	17·00	Nil	1·130	0·260	3·84	5·8	16·3	22·1	0·24	0·50
3rd June, 1904	2. 0 p.m.	0·5	43·2	70·2	113·4	32·2	18·2	50·4	12·50	Nil	3·304	0·685	7·06	5·7	10·6	16·3	0·00	1·57
2nd September, 1904	2. 0 p.m.	0·5	28·0	64·0	92·0	16·0	11·0	27·0	13·00	Nil	2·160	0·540	6·48	4·2	14·9	19·1	0·02	0·04
2nd December, 1904	2. 0 p.m.	0·5	29·6	62·4	92·0	16·6	18·4	35·0	17·00	Nil	2·197	0·472	7·6	4·3	16·3	20·6	0·07	0·12
AVERAGES:																		
March Samples	—	1·2	24·1	41·7	65·8	10·9	5·9	16·8	9·32	0·02	1·310	0·430	3·76	5·3	12·4	17·7	0·24	0·70
June Samples	—	0·8	40·1	71·9	112·0	28·6	13·0	41·6	14·06	Nil	2·806	0·839	7·60	6·5	13·1	19·6	0·02	0·41
September Samples ..	—	0·9	32·2	63·5	95·7	19·5	11·0	30·5	12·70	Nil	2·460	0·598	6·86	7·1	10·8	17·9	0·12	0·70
December Samples ..	—	0·9	27·4	59·6	87·0	16·3	21·6	37·9	10·08	Nil	1·490	0·459	5·22	4·6	13·9	18·5	0·37	0·82
TOTAL SAMPLES.....	—	1·0	30·9	59·3	90·2	18·7	13·2	31·9	11·54	00·1	2·010	0·577	5·90	5·9	12·5	18·4	0·19	0·67

Table XIV.—Analyses of Water of Spen Beck at junction with Calder.

Results Expressed in Parts per 100,000.

DATE.	Time.	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
	During hour commencing at		Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
1st December, 1899	2. 0 p.m.	1·0	23·6	130·8	154·4	16·8	0·8	17·6	15·80	Nil	1·230	0·350	3·73	15·0	19·5	34·5	0·00	0·00
2nd March, 1900	1.45 p.m.	1·5	16·0	78·0	94·0	8·0	4·0	12·0	10·82	0·18	0·270	0·140	1·56	11·0	23·5	34·5	0·08	1·33
1st June, 1900	1.55 p.m.	1·5	21·0	144·8	165·8	9·0	10·8	19·8	28·66	Nil	1·290	0·466	4·27	13·9	22·1	36·0	0·00	0·00
7th September, 1900	1.50 p.m.	1·5	16·0	114·8	130·8	5·4	3·2	8·6	31·00	0·02	0·890	0·270	2·35	17·0	14·0	31·0	0·00	0·15
7th December, 1900	1.50 p.m.	2·0	20·6	66·0	86·6	4·6	1·6	6·2	11·12	0·26	0·164	0·130	1·21	11·0	23·5	34·5	0·68	1·36
1st March, 1901	1.45 p.m.	1·0	24·2	94·2	118·4	9·2	13·2	22·4	14·60	Nil	0·490	0·230	2·88	19·0	18·5	37·5	0·28	0·51
7th June, 1901	1.25 p.m.	1·0	37·4	152·4	198·8	24·4	21·4	45·8	36·00	Nil	0·740	0·820	8·28	20·0	9·6	29·6	0·00	0·00
6th September, 1901	1.10 p.m.	1·0	20·0	127·0	167·0	10·8	4·6	15·4	52·50	Nil	1·080	0·400	7·42	9·5	9·5	19·0	0·00	0·00
6th December, 1901	1.15 p.m.	1·0	25·0	112·0	137·0	14·0	2·0	16·0	35·00	Nil	1·040	0·290	4·42	20·0	15·0	35·0	0·00	0·07
7th March, 1902	1.30 p.m.	1·0	24·0	110·4	134·4	11·0	9·4	20·4	20·00	Nil	0·460	0·200	2·48	11·5	19·5	31·0	0·00	0·01
6th June, 1902	1.10 p.m.	2·0	31·6	119·0	150·6	19·6	5·0	24·6	26·70	Nil	0·700	0·190	2·40	12·0	9·5	21·5	0·03	0·88
5th September, 1902	1.30 p.m.	1·0	23·0	153·0	176·0	16·0	21·0	37·0	46·20	Nil	1·000	0·680	7·00	9·4	26·6	36·0	0·00	0·11
5th December, 1902	1. 0 p.m.	2·2	16·4	83·6	100·0	5·4	4·6	10·0	13·50	0·40	0·160	0·120	2·22	9·4	26·6	36·0	0·02	1·13
6th March, 1903	1.30 p.m.	3·5	30·6	73·4	104·0	6·6	4·4	11·0	12·25	0·28	0·263	0·160	1·46	Nil	22·9	22·9	0·10	0·45
5th June, 1903	1.20 p.m.	2·2	20·6	131·0	151·6	5·6	6·0	11·6	24·40	Nil	0·570	0·320	2·10	19·6	16·4	36·0	0·00	0·07
4th September, 1903	1.20 p.m.	3·0	18·9	117·8	136·7	5·0	2·8	7·8	25·10	Nil	0·222	0·124	1·72	9·2	23·6	32·8	0·42	0·86
4th December, 1903	1. 0 p.m.	1·0	22·0	91·4	113·4	12·0	18·4	30·4	14·50	0·05	0·280	0·220	3·04	10·6	20·6	31·2	0·20	0·57
4th March, 1904	1. 5 p.m.	2·2	20·2	92·7	112·9	6·6	4·9	11·5	16·75	0·11	0·280	0·104	1·84	14·8	13·3	28·1	0·10	0·24
3rd June, 1904	1.30 p.m.	4·0	15·0	121·2	136·2	3·0	2·2	5·2	30·00	Nil	0·430	0·100	1·62	18·5	9·6	28·1	0·01	1·28
2nd September, 1904	1.15 p.m.	2·0	19·8	151·2	171·0	5·8	4·2	10·0	63·75	Nil	0·807	0·270	3·56	16·4	13·3	29·7	0·00	0·02
2nd December, 1904	1.15 p.m.	1·2	26·1	126·8	152·9	11·5	8·8	20·3	36·50	0·08	0·360	0·240	3·71	14·1	15·6	29·7	0·01	0·02
Averages:																		
March Samples	—	1·8	23·0	89·7	112·7	8·28	7.18	15·46	14·88	0·11	0·353	0·167	2·04	11·3	19·5	30·8	0·11	0·51
June Samples	—	2·1	25·1	133·7	158·8	12·34	9·07	21·41	29·15	Nil	0·746	0·379	3·73	16·8	13·4	30·2	0·01	0·45
September Samples	—	1·7	19·5	136·8	156·3	8·60	7·16	15·76	43·69	0·01	0·800	0·349	4·41	12·3	17·4	29·7	0·08	0·23
December Samples	—	1·4	22·3	101·8	124·1	10·72	6·03	16·75	21·07	0·13	0·539	0·225	3·05	13·4	20·1	33·5	0·15	0·52
Total Samples	—	1·8	22·5	114·8	137·3	10·02	7·30	17·32	26·91	0·07	0·606	0·277	3·30	13·4	17·8	31·2	0·09	0·43

TABLE XV.—ANALYSES OF WATER OF RIVER DON AT FOOTBRIDGE, WORTLEY.

Results expressed in parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	11. 0 a.m.	—	4·3	15·4	19·7	—	—	—	2·30	—	0·016	0·003	0.05	2·8	8·8	11·6	0·00	1·83
2nd December, 1898	11. 0 a.m.	7·0	3·6	14·0	17·6	—	—	—	1·70	0·14	0·012	0·008	0.16	1·0	7·4	8·4	0·41	0·71
3rd March, 1899	11. 0 a.m.	24·0	3·8	17·4	21·2	—	—	—	2·30	0·10	0·016	0·006	0.04	1·2	9·9	11·1	0·00	0·00
2nd June, 1899	11. 0 a.m.	24·0	2·8	14·0	16·8	—	—	—	2·90	0·08	0·012	0·005	0.05	Nil	8·8	8·8	0·00	0·00
1st September, 1899	11. 0 a.m.	22·0	5·1	17·2	22·3	—	—	—	2·34	Nil	0·034	0·007	0·04	Nil	11·0	11·0	0·22	0·92
1st December, 1899	11. 0 a.m.	22·0	4·6	16·8	21·4	—	—	—	2·63	0·05	0·026	0·010	0.05	1·0	11·0	12·0	0·00	0·02
7th March, 1900	11. 0 a.m.	10·5	3·6	16·2	19·8	—	—	—	2·34	0·06	0·016	0·006	0.08	Nil	12·0	12·0	0·07	1·30
1st June, 1900	11. 0 a.m.	23·0	4·8	18·8	23·6	—	—	—	2·46	0·04	0·027	0·009	0.06	Nil	12·5	12·5	0·00	0·03
7th September, 1900	11. 0 a.m.	24·0	4·1	20·2	24·3	—	—	—	2·34	0·06	0·020	0·006	0.04	Nil	15·0	15·0	0·00	0·23
7th December, 1900	11. 0 a.m.	5·0	5·5	15·3	20·8	0·7	1·3	2·0	2·34	0·12	0·012	0·010	0.14	Nil	10·3	10·3	0·82	2·76
1st March, 1901	11. 0 a.m.	9·0	4·4	11·6	16·0	—	—	—	2·16	0·10	0·024	0·009	0.12	1·5	7·5	9·0	0·43	0·89
7th June, 1901	11. 0 a.m.	24·0	4·8	20·0	24·8	—	—	—	2·50	0·04	0·015	0·014	0.05	Nil	11·8	11·8	0·00	0·14
6th September, 1901	11. 0 a.m.	—	5·2	20·4	25·6	—	—	—	2·20	0·04	0·024	0·011	0.05	Nil	13·5	13·5	0·00	0·34
6th December, 1901	11. 0 a.m.	18·0	4·4	18·0	22·4	—	—	—	2·20	0·11	0·005	0·006	0.06	Nil	12·0	12·0	0·06	0·16
7th March, 1902	11. 0 a.m.	13·0	4·8	17·0	21·8	0·4	0·2	0·6	2·50	0·10	0·022	0·008	0·06	Nil	12·0	12·0	0·01	0·02
6th June, 1902	11. 0 a.m.	18·0	4·4	16·4	20·8	—	—	—	2·50	0·06	0·030	0·014	0·05	Nil	11·0	11·0	0·39	1·22
5th September, 1902	11. 0 a.m.	—	4·0	22·8	26·8	—	—	—	2·50	0·04	0·036	0·004	0·32	Nil	14·0	14·0	0·03	0·31
5th December, 1902	11. 0 a.m.	7·0	5·4	15·2	20·6	0·6	0·8	1·4	2·50	0·16	0·016	0·016	0·09	Nil	11·0	11·0	0·00	1·65
6th March, 1903	11. 0 a.m.	7·0	4·1	13·3	17·4	0·5	0·9	1·4	2·25	0·14	0·010	0·007	0·15	Nil	11·8	11·8	0·65	1·95
5th June, 1903	11. 0 a.m.	18·0	3·4	20·3	23·7	—	—	—	2·25	0·08	0·014	0·004	0·04	Nil	14·0	14·0	0·00	0·09
4th September, 1903	11. 0 a.m.	16·0	3·2	14·4	17·6	0·3	0·4	0·7	2·25	Trace	0·019	0·010	0·11	Nil	7·4	7·4	0·96	1·52
4th December, 1903	11. 0 a.m.	5·0	3·6	10·2	13·8	0·4	1·8	2·2	1·75	0·14	0·012	0·014	0·34	Nil	6·7	6·7	1·21	1·86
4th March, 1904	11. 0 a.m.	11·0	4·2	16·6	20·8	0·2	0·4	0·6	2·55	0·07	0·023	0·006	0·08	Nil	9·6	9·6	0·19	0·36
3rd June, 1904	11. 0 a.m.	15·0	4·4	15·6	20·0	0·4	0·4	0·8	2·25	0·06	0·020	0·007	0·09	Nil	8·1	8·1	0·03	1·42
2nd September, 1904	11. 0 a.m.	20·0	4·4	17·2	21·6	0·0	0·4	0·4	2·50	0·06	0·025	0·007	0·07	Nil	8·9	8·9	0·02	0·02
2nd December, 1904	11. 0 a.m.	16·0	3·8	13·2	17·0	0·2	0·4	0·6	2·25	0·13	0·022	0·007	0·10	Nil	7·9	7·9	0·12	0·14
AVERAGES:																		
March Samples	—	12·4	4·2	15·3	19·5	—	—	—	2·30	0·10	0·018	0·007	0·09	0·4	10·4	10·8	0·22	0·76
June Samples	—	20·3	4·1	17·5	21·6	—	—	—	2·47	0·05	0·019	0·009	0·06	Nil	11·0	11·0	0·07	0·48
September Samples	—	20·5	4·3	18·2	22·5	—	—	—	2·35	0·03	0·025	0·007	0·10	0·4	11·2	11·6	0·17	0·74
December Samples	—	11·4	4·4	14·7	19·1	—	—	—	2·19	0·12	0·015	0·010	0·13	0·3	9·5	9·8	0·37	1·04
TOTAL SAMPLES	—	15·6	4·3	16·4	20·7	—	—	—	2·23	00·8	0·019	0·009	00·9	0·3	10·5	10·8	0·21	0·76

TABLE XVI.—ANALYSES OF WATER OF RIVER DON AT KILNHURST

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution. Loss on Ignition.	Ash.	Total.	Solids in Suspension only. Loss on Ignition.	Ash.	Total.	Chlorides (as Na Cl).	Nitrogen. Nitric.	Ammoniacal (from Free and Saline Amm.)	Albuminoid (Wanklyn.)	Oxygen absorbed in 4 hours at 80° F.	Hardness. Temp.	Perm.	Total.	Rainfall in ins. at selected stations. During preceding two days.	During preceding week.
6th December, 1901	1.50 p.m.	6·0	10·4	56·8	67·2	1·4	0·8	2·2	20·50	0·05	0·710	0·078	0·69	0·0	24·0	30·0	0·06	0·16
7th March, 1902	2. 0 p.m.	9·0	7·9	47·2	55·1	1·1	0·4	1·5	13·70	0·16	0·520	0·147	0.44	6·5	19·5	26·0	0·01	0·02
6th June, 1902	2.20 p.m.	10·0	8·1	49·2	37·3	0·5	1·2	1·7	17·20	0·08	0·280	0·025	0.26	4·5	20·5	25·0	0·39	1·22
5th September, 1902	3. 0 p.m.	6·5	14·0	63·2	77·2	0·8	0·8	1·6	26·20	Nil	0·800	0·075	0.43	7·7	25·1	32·8	0·03	0·31
5th December, 1902	2.10 p.m.	6·0	7·1	39·2	46·3	1·1	2·4	3·5	9·25	0·36	0·127	0·037	0.43	0·0	25·9	25·9	0·00	1·65
6th March, 1903	2. 0 p.m.	5·5	8·9	36·1	45·0	2·1	2·5	4·6	11·50	0·17	0·100	0·026	0.54	3·2	18·0	21·2	0·65	1·95
5th June, 1903	2.10 p.m.	8·0	13·2	78·2	91·4	1·2	0·6	1·8	31·00	Nil	0·517	0·060	0.37	3·2	34·4	37·6	0·00	0·09
4th September, 1903	3.30 p.m.	5·5	6·4	43·4	49·8	0·4	1·4	1·8	17·50	Trace	0·265	0·022	0.40	2·3	13·3	15·6	0·96	1·52
4th December, 1903	2. 0 p.m.	3·2	8·0	35·6	43·6	1·2	6·0	7·2	7·50	0·22	0·122	0·038	0.72	3·0	12·6	15·6	1·21	1·86
4th March, 1904	2. 0 p.m.	11·5	9·4	57·9	67·3	0·6	0·7	1·3	15·25	0·19	0·314	0·034	0.41	Nil	12·6	12·6	0·19	0·36
3rd June, 1904	2. 0 p.m.	7·5	8·8	54·5	63·3	0·8	0·9	1·7	19·50	0·06	0·353	0·030	0.44	0·8	16·4	17·2	0·03	1·42
2nd September, 1904	2.15 p.m.	6·0	13·2	69·1	82·3	0·2	1·1	1·3	28·00	Nil	0·716	0·060	0.55	3·2	18·0	21·2	0·02	0·02
2nd December, 1904	2. 0 p.m.	7·5	7·2	50·5	57·7	0·8	1·3	2·1	20·00	0·04	0·383	0·037	0.47	0·8	14·8	15·6	0·12	0·14
AVERAGES:																		
March Samples	—	8·7	8·7	47·1	55·8	1·3	1·2	2·5	13·48	0·17	0·311	0·036	0·46	3·2	16·7	19·9	0·28	0·77
June Samples	—	8·5	10·0	60·6	70·6	0·8	0·9	1·7	2·60	0·04	0·383	0·038	0.36	2·8	23·8	26·6	0·14	0·91
September Samples ..	—	6·0	11·2	58·6	69·8	0·5	1·1	1·6	23·90	Nil	0·593	0·052	0.46	4·4	18·8	23·2	0·34	0·62
December Samples ..	—	5·7	8·2	45·5	53·7	1·1	2·6	3·7	14·30	0·17	0·335	0·047	0·57	2·4	19·3	21·7	0·34	0·95
TOTAL SAMPLES.....	—	7·1	9·4	52·4	61·8	0·9	1·6	2·5	18·23	0·10	0·400	0·043	0·47	3·2	19·6	22·8	0·28	0·82

TABLE XVII.—ANALYSES OF WATER OF RIVER DON AT CONISBOROUGH.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution. Loss on Ignition.	Ash.	Total.	Solids in Suspension only. Loss on Ignition.	Ash.	Total.	Chlorides (as Na Cl).	Nitrogen. Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)	Oxygen absorbed in 4 hours at 80° F.	Hardness. Temp.	Perm.	Total.	Rainfall in ins. at selected stations. During preceding two days.	During preceding week.
2nd September, 1898	11. 0 a.m.	—	5·4	53·4	58·8	—	—	—	18·70	—	0·270	0·026	0·28	4·5	15·3	19·8	0·00	1·83
2nd December, 1898	11.30 a.m.	11·5	8·3	66·8	75·1	—	—	—	15·20	0·44	0·113	0·015	0·23	6·4	19·6	26·0	0·41	0·71
3rd March, 1899	11.30 a.m.	12·5	12·0	66·9	78·9	—	—	—	19·30	0·26	0·240	0·034	0·29	12·1	21·4	33·5	0·00	0·00
2nd June, 1899.....	11.30 a.m.	11·0	11·6	93·3	104·9	—	—	—	36·30	0·10	0·113	0·023	0·23	7·7	18·8	26·5	0·00	0·00
1st September, 1899	11.30 a.m.	9·5	12·0	112·8	124·8	0·4	1·6	2·0	50·31	Nil	0·762	0·063	0·41	14·3	26·5	40·8	0·22	0·92
1st December, 1899	11.30 a.m.	12·0	8·0	80·0	88·0	0·4	1·2	1·6	30·40	0·01	0·530	0·053	0·41	13·0	23·0	36·0	0·00	0·02
2nd March, 1900	11.30 a.m.	7·5	8·4	38·4	46·8	1·2	1·6	2·8	7·17	0·25	0·045	0·023	0·26	2·0	19·0	21·0	0·07	1·30
1st June, 1900	11.30 a.m.	8·5	9·6	88·8	98·4	1·0	2·4	3·4	31·00	Nil	1·000	0·05	0·53	13·0	23·0	36·0	0.00	0·03
7th September, 1900	2. 0 p.m.	11·0	—	—	80·9	—	—	·40	26·32	Nil	0·530	0·030	0·26	6·0	30·0	36·0	0·00	0·23
7th December, 1900	11.30 a.m.	3·0	9·5	39·3	48·8	2·3	6·9	9·2	6·14	0·24	0·063	0·037	0·55	3·0	19·0	22·0	0·82	2·76
1st March, 1901	11.30 a.m.	12·0	12·2	39·2	51·4	0·2	1·2	1·4	12·00	1·10	0·266	0·033	0·28	5·5	21·0	26·5	0·43	0·89
7th June, 1901	11.30 a.m.	11.5	14·8	86·8	101·6	0·8	0·8	1·6	33·00	Nil	0·990	0·073	0·35	4·0	33·0	37·0	0·00	0·14
6th September, 1901	11.30 a.m.	7·0	11·0	98·0	109·0	0·9	0·7	1·6	40·70	Trace	0·890	0·090	0·37	Nil	38·0	38·0	0·00	0·34
6th December, 1901	11.30 a.m.	10·5	8·5	63·9	72·4	0·5	0·9	1·4	22·00	0 09	0·570	0·056	0·53	3·0	23·0	31·0	0·06	0·16
7th March, 1902	11.30 a.m.	13·0	9·1	54·9	64·0	0·7	0·5	1·2	13·00	0·21	0·260	0·030	0·27	9·0	23·0	32·0	0·01	0·02
6th June, 1902	11.30 a.m.	13·0	8·2	50·9	59·1	0·2	1·3	1·5	15·50	0·06	0·440	0·030	0·26	7·0	21·0	28·0	0·39	1·22
5th September, 1902	11.30 a.m.	17·5	9·0	76·8	85·8	0·0	0·8	0·8	30·30	Nil	0·750	0·040	0·35	4·8	29·6	34·4	0·03	0·31
5th December, 1902	11.30 a.m.	24·0	8·9	52·9	61·8	0·5	1·3	1·8	8·87	0·36	0·073	0·029	0·33	Nil	31·2	31·2	0·00	1·65
6th March, 1903	11.30 a.m.	6·0	7·6	21·3	28·9	2·2	1·9	4·1	9·00	0·20	0·149	0·026	0·52	1·6	18·8	20·4	0·65	1·95
5th June, 1903	11.30 a.m.	9·0	10·5	66·2	76·7	0·5	0·6	1·1	22·00	0·06	0·426	0·032	0·19	4·8	31·2	36·0	0·00	0·09
4th September, 1903	11.30 a.m.	6·0	7·8	45·2	53·0	0·6	1·2	1·8	13·50	Trace	0·295	0·032	0·41	2·4	14·8	17·2	0·96	1·52
4th December, 1903	2.10 p.m.	2·7	13·4	42·0	55·4	3·4	8·0	11·4	8·00	0·18	0·130	0·37	0·96	1·6	14·0	15·6	1·21	1·86
4th March, 1904	11.30 a.m.	14·5	7·5	54·1	61·6	0·3	0·5	0·8	11·75	0·18	0·270	0·029	0·35	1·5	22·1	23·6	0·19	0·36
3rd June, 1904	11.30 a.m.	8·5	9·5	53·2	62·7	0·7	0·8	1·5	15·00	Nil	0·420	0·038	0·54	4·7	13·3	18·0	0·03	1·42
2nd September, 1904	11.30 a.m.	15·0	13·0	78·4	91·4	0·0	0·4	0·4	35·00	Nil	0·716	0·060	0·49	3·2	18·0	21·2	0·02	0·02
2nd December, 1904	11.30 a.m.	8·0	7·2	52·2	59·4	0·6	0·8	1·4	17·75	0·06	0·420	0·037	0·46	1·6	14·0	15·6	0·12	0·14
AVERAGES:																		
March Samples	—	10·9	9·4	45·8	55·2	0·8	0·9	1·7	12·03	0·20	0·205	0·029	0·33	5·3	20·8	26·1	0·22	0·75
June Samples	—	10·2	10·7	73·2	83·9	0·5	1·0	1·5	25·40	·04	0·564	0·041	0·35	6·8	23·4	30·2	0·07	0·48
September Samples ..	—	11·0	9·6	76·6	86·2	0·3	0·7	1·0	30·69	Nil	0·601	0·048	0·36	5·0	24·6	29·6	0·17	0·74
December Samples ..	—	10·2	9·1	56·7	65·8	1·1	2·7	3·8	15·48	0·20	0·281	0·039	0·49	4·1	21·2	25·3	0·37	1·04
TOTAL SAMPLES.. ...	—	**10·6**	**9·7**	**63·3**	**73·0**	**0·7**	**1·3**	**2·0**	**21·00**	**0·11**	**0·410**	**0·039**	**0·38**	**5·2**	**22·5**	**27·7**	**0·21**	**0·76**

Table XVIII.—Analyses of Water of River Tame at Mossley Bridge.

Results Expressed in Parts per 100,000.

DATE.	Time. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd June, 1899	2.30 p.m.	6·5	7·0	15·3	22·3	0·4	0·2	0·6	4·10	0·04	0·016	0·085	0·90	2·8	3·8	6·7	0·00	0·00
1st September, 1899	2.30 p.m.	6·5	5·2	13·0	18·2	0·9	0·2	1·1	3·51	Nil	0·048	0·048	0·68	2·0	6·0	8·0	0·35	1·62
1st December, 1899	2.30 p.m.	1·0	34·0	54·7	88·7	29·6	40·7	70·3	3·21	0·06	0·024	0·387	6·10	0·7	8·3	9·0	0·05	0·12
2nd March, 1900	2.30 p.m.	10·0	3·2	10·8	14·0	—	—	—	2·63	0·16	0·027	0·016	0·43	0·3	6·4	6·7	0·04	1·35
1st June, 1900	2.30 p.m.	5·0	7·8	21·0	28·3	2·2	0·2	2·4	4·09	Nil	0·030	0·125	1·44	3·0	7·3	10·3	0·00	0·02
7th September, 1900	2.30 p.m.	4·0	7·8	17·4	25·2	1·5	2·3	3·8	3·51	Nil	0·036	0·114	0·99	1·8	7·7	99·5	0·00	0·36
7th December, 1900	2.30 p.m.	10·5	4·5	9·7	14·2	1·0	0·9	1·9	2·19	0·11	0·024	0·035	0·29	Nil	6·0	6·0	0·55	1·74
1st March, 1901	2.30 p.m.	8·0	7·2	9·4	16·6	1·2	1·4	2·6	2·48	0·14	0·040	0·030	0·41	Nil	5·0	5·0	0·38	0·89
7th June, 1901	2.30 p.m.	4·0	8·4	26·0	34·4	4·4	2·0	6·4	4·70	Nil	0·044	0·209	1·77	—	—	11·8	0·00	0·18
6th September, 1901	2.30 p.m.	4·0	8·0	21·0	29·0	2·4	2·8	5·2	4·20	Nil	0·060	0·090	1·40	3·0	7·5	10·5	0·00	0·27
6th December, 1901	2.30 p.m.	6·0	4·9	17·0	21·9	1·9	1·0	2·9	3·50	0·10	0·076	0·056	0·93	0·5	7·3	7·8	0·06	0·16
7th March, 1902	2.30 p.m.	9·0	6·4	16·4	22·8	1·2	1·2	2·4	3·50	0·11	0·035	0·050	0·60	2·5	5·0	7·5	0·00	0·00
6th June, 1902	2.30 p.m.	6·0	5·6	18·4	24·0	1·2	1·2	2·4	3·50	Nil	0·100	0·080	1·30	1·0	7·5	8·5	0·14	0·45
5th September, 1902	2.30 p.m.	5·5	10·4	20·6	31·0	2·4	1·6	4·0	3·75	Nil	0·035	0·110	1·30	0·7	8·1	8·8	0·11	0·29
5th December, 1902	2.30 p.m.	7·0	4·8	16·4	21·2	0·8	0·4	1·2	2·75	0·06	0·030	0·046	1·03	0·7	7·6	8·3	0·00	1·37
6th March, 1903	2.30 p.m.	10·5	4·2	11·1	15·3	0·6	0·7	1·3	2·75	0·12	0·017	0·016	0·34	Nil	7·4	7·4	0·39	1·23
5th June, 1903	2.30 p.m.	16·5	3·5	13·7	17·2	0·1	0·3	0·4	3·25	0·07	0·070	0·018	0·18	0·7	8·1	8·8	0·00	0·06
4th September, 1903	2.30 p.m.	14·0	4·7	11·4	16·1	0·5	0·7	1·2	2·75	0·12	0·016	0·023	0·34	Nil	6·7	6·7	0·66	1·48
4th December, 1903	2.30 p.m.	4·7	4·8	11·1	15·9	1·5	2·2	3·7	2·25	0·09	0·035	0·034	0·71	Nil	4·5	4·5	0·72	1·19
4th March, 1904	2.30 p.m.	6·0	5·2	13·0	18·2	0·8	0·6	1·4	2·50	0·14	0·022	0·038	0·68	Nil	6·7	6·7	0·11	0·14
3rd June, 1904	2.30 p.m.	11·0	4·1	12·0	16·1	0·6	1·0	1·6	2·50	0·08	0·020	0·030	0·53	Nil	6·7	6·7	0·00	1·45
2nd September, 1904	2.30 p.m.	3·7	7·1	19·6	26·7	1·9	1·6	3·5	4·75	Nil	Trace	0·065	1·34	2·2	6·7	8·9	0·01	0·07
2nd December, 1904	2.30 p.m.	8·2	4·4	13·5	17·9	0·6	0·7	1·3	3·25	0·05	0·035	0·026	0·64	0·7	5·3	6·0	0·08	0·16
Averages:																		
March Samples	—	8·7	5·3	12·1	17·4	0·8	0·9	1·7	2·77	0·13	0·028	0·030	0·49	0·6	6·1	6·7	0·18	0·72
June Samples	—	8·2	6·1	17·7	23·8	1·5	0·8	2·3	3·69	0·31	0·047	0·090	1·02	1·4	7·4	8·8	0·02	0·36
September Samples	—	6·3	7·2	17·2	24·4	1·6	1·5	3·1	3·74	0·02	0·032	0·075	1·01	1·6	7·1	8·7	0·19	0·68
December Samples	—	6·2	9·6	20·4	30·0	5·9	7·7	13·6	2·86	0·08	0·037	0·097	1·81	0·4	6·5	6·9	0·24	0·79
Total Samples	—	**7·3**	**7·1**	**17·1**	**24·2**	**2·5**	**2·8**	**5·3**	**3·29**	**0·06**	**0·036**	**0·075**	**1·06**	**1·0**	**6·8**	**7·8**	**0·16**	**6·63**

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Mr. H. Maclean Wilson. 16 May 1905.

TABLE XIX.—ANALYSES OF WATER OF RIVER WHARFE AT ADDINGHAM BRIDGE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	2.30 p.m.	—	2.0	16·9	18·9	—	—	—	1·15	—	0·003	0·077	1·17	9·7	2·8	12·5	0·00	0·87
2nd December, 1898	2. 0 p.m.	4·5	3.1	11·2	14·3	—	—	—	1·17	0·04	0·003	0·020	0·78	2·8	4·6	7·4	0·06	0·20
3rd March, 1899	2.15 p.m.	24·0	2.0	15·5	17·5	—	—	—	1·70	0·03	Trace	0·004	0·15	10·0	2·6	12·6	0·00	0·02
2nd June, 1899	2.10 p.m.	24·0	2.6	14·1	16·7	—	—	—	2·04	0·01	0·002	0·011	0·24	8·3	2·0	10·3	0·00	0·09
1st September, 1899	2.30 p.m.	24·0	0.9	15·5	16·4	—	—	—	2·05	Nil	0·006	0·011	0·09	2·0	12·0	14·0	0·17	1·28
1st December, 1899	2.15 p.m.	24·0	3.2	15·4	18·6	—	—	—	2·05	0·04	0·002	0·003	0·13	8·0	6·0	14·0	0·00	0·00
2nd March, 1900	2. 0 p.m.	24·0	2.0	14·0	16·0	—	—	—	1·61	0·02	0·002	0·008	0·15	5·0	7·5	12·5	0·05	0·96
1st June, 1900	2.30 p.m.	24·0	2.0	13·8	15·8	—	—	—	1·75	0·01	0·002	0·008	0·25	3·0	8·0	11·0	0·00	0·09
1st September, 1900	1.45 p.m.	18·5	4.4	10·0	14·4	—	—	—	1·17	Nil	0·005	0·021	0·57	1·3	9·0	10·3	0·00	0·18
7th December, 1900	1.45 p.m.	24·0	3.2	14·0	17·2	—	—	—	1·46	0·02	0·007	0·013	0·31	6·0	6·0	12·0	0·77	1·63
7th March, 1901	2. 0 p.m.	15·5	4.0	11·6	15·6	—	—	—	1·87	0·06	0·101	0·011	0·33	0·5	9·0	9·5	0·52	0·83
7th June, 1901	2.15 p.m.	24·0	1.6	17·6	19·2	—	—	—	2·00	0·04	0·007	0·011	0·12	—	—	14·0	0·00	0·12
6th September, 1901	1.30 p.m.	—	2.4	12·8	15·2	—	—	—	1·20	Nil	0·006	0·011	0·33	3·0	7·5	10·5	0·00	0·07
9th December, 1901	1. 0 p.m.	20·0	2.0	14·2	16·2	—	—	—	1·20	0·05	0·006	0·007	0·29	7·0	5·0	12·0	0·02	0·07
7th March, 1902	2. 0 p.m.	17·5	2.4	13·6	16·0	—	—	—	1·80	0·03	0·003	0·008	0·15	4·0	7·0	11·0	0·01	0·03
6th June, 1902	1.30 p.m.	24·0	2.0	15·2	17·2	—	—	—	1·50	Nil	0·006	0·010	0·26	6·0	6·0	12·0	0·20	0·63
5th September, 1902	2. 0 p.m.	—	2.8	15·6	18·4	—	—	—	1·50	Trace	Trace	0·012	0·30	6·6	6·7	13·3	0·00	0·22
5th December, 1902	2. 0 p.m.	24·0	2.4	17·2	19·6	—	—	—	1·62	0·07	Trace	0·011	0·15	7·8	7·0	14·8	0·02	1·30
6th March, 1903	2. 0 p.m.	24·0	2.8	12·0	14·8	—	—	—	2·00	0·02	0·004	0·005	0·17	5·9	7·4	13·3	0·56	1·37
5th June, 1903	2. 0 p.m.	24·0	3.8	11·2	15·0	—	—	—	1·75	0·02	Trace	0·008	0·30	2·9	7·4	10·5	0·04	0·09
4th September, 1903	2. 0 p.m.	25·0	2.0	16·0	18·0	—	—	—	1·15	Trace	0·005	0·009	0·34	6·6	7·4	14·0	0·55	1·15
4th December, 1903	2. 0 p.m.	12·5	3.2	10·0	13·2	—	—	—	1·50	Slt. Tr.	0·006	0·010	0·43	Nil	9·6	9·6	0·44	1·89
4th March, 1904	2. 0 p.m.	24·0	3.6	12·4	16·0	—	—	—	1·75	Trace	0·003	0·009	0·22	4·7	8·6	13·3	0·07	0·25
3rd June, 1904	1.15 p.m.	24·0	2.8	14·8	17·6	—	—	—	1·50	0·02	Nil	0·004	0·22	4·7	8·6	13·3	0·00	1·36
2nd September, 1904	2. 0 p.m.	24·0	4.0	12·0	16·0	—	—	—	1·00	Nil	0·004	0·012	0·37	4·2	8·1	12·3	0·00	0·00
2nd December, 1904	2.0 p.m.	24·0	3.2	10·4	13·6	—	—	—	1·25	0·02	0·003	0·012	0·43	0·7	9·6	10·3	0·12	0·22
AVERAGES:																		
March Samples	—	21·5	2·8	13·2	16·0	—	—	—	1·79	0·03	0·004	0·007	0·19	5·0	7·0	12·0	0·20	0·58
June Samples	—	24·9	2·5	14·4	16·9	—	—	—	1·76	0·02	0·003	0·009	0·23	5·1	6·7	11·8	0·04	0·38
September Samples	—	22 9	2·6	14·1	16·7	—	—	—	1·32	Nil	0·004	0·012	0·32	4·8	7·6	12·4	0·10	0·54
December Samples	—	18·9	2·9	13·2	16·1	—	—	—	1·46	0·03	0·004	0·011	0·36	4·6	6·8	11·4	0·20	0·76
TOTAL SAMPLES	—	**21·6**	**2·7**	**13·7**	**16·4**	—	—	—	**1·57**	**0·02**	**0·004**	**0·010**	**0·28**	**4·9**	**7·0**	**11·9**	**0·14**	**0·57**

TABLE XX.—ANALYSES OF WATER OF RIVER WHARFE AT POOL BRIDGE.

Results Expressed in Parts per 100,000.

DATE.	TIME. During hour commencing at	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall in ins. at selected stations.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	During preceding two days.	During preceding week.
2nd September, 1898	10.30 a.m.	—	1·8	13·0	14·8	—	—	—	1·15	—	0·008	0·017	0·51	9·0	3·1	12·1	0·00	0·87
2nd December, 1898	10.30 a.m.	8·5	2·0	11·3	13·3	—	—	—	1·05	0·06	0·009	0·009	0·50	2·7	5·6	8·1	0·06	0·20
3rd March, 1899	10.50 a.m.	24·0	3·2	16·4	19·6	—	—	—	2·20	0·08	0·005	0·006	0·16	9·5	3·8	13·3	0·00	0·02
2nd June, 1899.....	10.30 a.m.	24·0	6·8	13·2	20·0	—	—	—	2·60	0·03	0·007	0·009	0·19	8·5	4·0	12·5	0·00	0·00
1st September, 1899	11. 0 a.m.	24·0	2·4	18·4	20·8	—	—	—	2·34	0·00	0·021	0·021	0·20	11·5	2·0	13·5	0·17	1·28
1st December, 1899	10.30 a.m.	24·0	2·6	15·8	18·4	—	—	—	2·34	0·03	0·010	0·008	0·21	7·3	6·7	14·0	0·00	0·00
2nd March, 1900	10.30 a.m.	24·0	3·0	13·0	16·0	—	—	—	1·75	0·05	0·002	0·009	0·21	3·8	8·0	11·8	0·05	0·96
1st June, 1900	11. 0 a.m.	24·0	2·2	16·0	18·2	—	—	—	2·04	0·00	0·003	0·009	0·22	6·2	6·3	12·5	0·00	0·09
7th September, 1900	10.30 a.m.	17·0	3·5	12·7	16·2	—	—	—	1·46	0·02	0·009	0·027	0·51	4·5	7·0	11·5	0·00	0·18
7th December, 1900	10.30 a.m.	17·5	3·6	12·4	16·0	—	—	—	2·05	0·02	0·006	0·017	0·38	2·0	7·5	9·5	0·77	1·63
1st March, 1901	10.30 a.m.	13·5	4·4	14·8	19·2	—	—	—	2·16	0·08	0·008	0·015	0·25	0·5	7·5	8·0	0·52	0·83
7th June, 1901	11. 0 a.m.	24·0	2·0	17·2	19·2	—	—	—	2·20	0·33	0·008	0·015	0·19	5·5	7·0	12·5	0·00	0·12
6th September, 1901	11. 0 a.m.	—	2·8	15·6	18·4	—	—	—	1·50	0·00	0·005	0·008	0·22	7·0	6·0	13·0	0·00	0·07
6th December, 1901	10. 0 a.m.	24·0	2·4	16·4	18·8	—	—	—	1·50	0·05	0·006	0·011	0·27	7·0	7·0	14·0	0·02	0·07
7th March, 1902	10.30 a.m.	24·0	4·4	14·8	19·2	—	—	—	2·00	0·02	0·010	0·101	0·15	5·5	7·0	12·5	0·01	0·03
6th June, 1902	10.30 a.m.	24·0	2·2	16·4	18·6	—	—	—	1·50	0·04	0·015	0·017	0·29	5·0	7·5	12·5	0·20	0·63
5th September, 1902	10.45 a.m.	—	2·8	16·0	18·8	—	—	—	2·10	Trace	0·004	0·014	0·30	4·8	8·8	13·6	0·00	0·22
5th December, 1902	10.30 a.m.	24·0	2·8	18·4	21·2	—	—	—	1·75	0·09	Trace	0·013	0·20	4·8	9·3	14·1	0·02	1·30
6th March, 1903	10.30 a.m.	24·0	5·2	10·4	15·6	—	—	—	2·25	0·03	do.	0·006	0·22	3·0	9·6	12·6	0·56	1·37
5th June, 1903	10.30 a.m.	24·0	2·8	15·6	18·4	—	—	—	2·25	0·04	0·006	0·014	0·24	3·7	8·8	12·5	0·04	0·09
4th September, 1903	10.30 a.m.	17·0	3·2	14·8	18·0	—	—	—	1·25	Nil	Trace	0·014	0·47	5·2	7·4	12·6	0·55	1·15
4th December, 1903	10.15 a.m.	5·5	3·7	11·1	14·8	0·5	2·7	3·2	1·00	Sll. Tr.	0·011	0·020	0·57	Nil	8·1	8·1	0·44	1·89
4th March, 1904	10.30 a.m.	21·0	4·0	13·0	17·0	—	—	0·2	1·00	0·03	0·013	0·011	0·25	3·0	8·8	11·8	0·07	0·25
3rd June, 1904	10.30 a.m.	24·0	2·7	15·1	17·8	—	—	0·5	1·50	0·03	0·005	0·009	0·33	4·4	8·1	12·5	0·00	1·36
2nd September, 1904	10.30 a.m.	23·5	5·2	14·1	19·3	—	—	0·1	2·50	Trace	0·013	0·014	0·29	8·1	6·7	14·8	0·00	0·00
2nd December, 1904	10.15 a.m.	19·0	3·7	10·5	14·2	—	—	0·6	1·25	0·34	0·005	0·014	0·43	Nil	9·6	9·6	0·32	0·22
AVERAGES:																		
March Samples	—	21·7	3·8	13·8	17·6	—	—	—	1·89	0·05	0·006	0·009	0·21	4·2	7·5	11·7	0·20	0·58
June Samples	—	24·0	3·1	15·6	18·7	—	—	—	2·01	0·03	0·007	0·012	0·24	5·5	7·0	12·5	0·04	0·38
September Samples ..	—	20·4	3·1	14·9	18·0	—	—	—	1·76	0·01	0·009	0·016	0·36	7·1	5·9	13·0	0·10	0·54
December Samples ..	—	17·5	3·0	13·7	16·7	—	—	—	1·56	0·04	0·007	0·132	0·36	3·4	7·7	11·1	0·20	0·76
TOTAL SAMPLES	—	**20·8**	**3·2**	**14·5**	**17·7**	—	—	—	**1·80**	**0·03**	**0·007**	**0·013**	**0·30**	**5·1**	**7·0**	**12·1**	**0·14**	**0·57**

Mr. H. Marlean Wilson.
16 May 1905.

TABLE XXI.—ANALYSES OF RIVER WATERS DURING FLOODS.

Results Expressed in Parts per 100,000.

	Time.	Transparency in inches.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.			Rainfall.
	During hour commencing at		Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn.)		Temp.	Perm.	Total.	
River Calder at Wakefield on 12th and 13th November, 1901, during a heavy flood after drought:—																	
A. Taken while river rising ..... (12th November)	11.40 a.m.	1·0	282·0	426·4	708·4	276·0	382·0	658·0	10·25	Nil	1·16	6·28	64·30	12·0	18·0	30·0	11th Nov., 1901..1·35 in. 12th Nov., 1901..1·46 in.
B. At height of flood ..... (12th November)	3.30 p.m.	1·0	60·6	177·2	237·8	57·0	160·0	217·0	3·75	0·14	0·25	0·89	8·76	1·5	10·5	12·0	
C. While river falling ..... (13th November)	11. 0 a.m.	1·5	10·4	37·6	48·0	5·2	17·6	22·8	3·75	0·35	0·10	0·11	1·28	0·5	10·5	11·0	
D. While still falling ..... (13th November)	3.30 p.m.	1·5	12·0	36·8	48·8	4·4	17·2	21·6	4·00	0·31	0·08	0·10	1·26	0·5	12·0	12·5	
River Don on 29th December, 1899, during flood:—																	
E. At Wardsend Bridge.....	1.40 p.m.	—	14·4	64·4	78·8	9·6	50·6	60·2	—	—	—	—	1·49	—	—	—	28th Dec., 1899..0·73 in. 29th Dec., 1899..0·36 in. (Snow previously.)
F. Above junction with Loxley	2. 0 p.m.	—	13·2	55·2	68·4	7·0	40·0	47·0	—	—	—	—	1·54	—	—	—	
G. At Malm Bridge above junction with Rivelin	2.30 p.m.	—	16·0	56·2	72·2	10·6	39·6	50·2	—	—	—	—	1·41	—	—	—	
H. At Hillfoot Forge, Nether Slack..	1. 0 p.m.	—	11·2	35·2	46·4	3·9	20·4	24·3	—	—	—	—	0·82	—	—	—	
I. At Norfolk Bridge	12. 0 noon	—	17·0	62·6	79·6	10·8	46·1	56·9	—	—	—	—	1·57	—	—	—	

TABLE XXII.—ANALYSES OF SLUDGES TAKEN FROM MILL DAMS.

Results Expressed in Parts per 100.

DATE.	Sanitary District.	Stream.	Works and Firm.	Wet Sludge.			Moisture-free Sludge.					
				Moisture.	Loss on Ignition.	Ash.	Volatile Matter.	Ash.	Ash.			Total Nitrogen (Kj).
									Silica.	Iron and Alumina (as oxides).	Lime (as oxide).	
20th May, 1898 ..	Wortley Rural ..	Loxley	Hibbert Wheel .. .. .. (B. Swift)	82·52	4·04	13·44	23·12	76·88	—	17·39	—	0·32
3rd June, 1898 ..	Sheffield ..	Don	Attercliffe Steel Works .. (Sanderson Bros. & Co., Ltd.)	74·51	6·95	18·54	27·27	72·73	41·54	14·82	—	0·65
4th June, 1898 ..	Todmorden ..	Dules Gate Clough	Stoneswood Mill .. .. (T. & J. Walton)	54·20	8·65	37·15	18·89	81·11	—	16·70	—	0·41
16th August, 1902	Sowerby	Ryburn	Thorpe Mill .. .. (F. E. Rawson)	74·70	12·27	13·03	48·50	51·50	37·30	11·00	0·70	0·77
				24·61	34·02	41·37	45·12	54·88	38·68	13·08	0·60	0·25
				31·25	5·50	63·25	8·00	92·00	80·90	8·70	0·60	0·16
Average analysis of 5 Surface Soils— (Stephenson & Murphy—Hygiene and Public Health, Vol. I., p. 388.) ..				—	—	—	5·58	94·42	76·04	13·53	1·86	0·15

TABLE XXIII.—ANALYSES OF WATERS TAKEN WHILE SLUDGING WAS PROCEEDING.

Results Expressed in Parts per 100,000.

DATE.	Sanitary District.	Stream.	Works and Firm.	Nature of Sample.	Solid matter in Suspension and Solution (dried at 100° C.)			Solid matter in Suspension only (dried at 100° C.)			Solid matter in Solution only (dried at 100° C.)			Nitrogen.			Oxygen absorbed in 4 hours at 80° F.
					Total.	Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Ammoniacal from Free and Saline Amm.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	
1st July, 1897 ..	Thurlstone	Don ..	Bullhouse Mill .. .. (Goldthorpe & Hinchliffe)	Water from mill dam	1107·2	153·2	954·0	1095·2	151·0	944·2	12·0	2·2	9·8	—	—	1·300*	—
3rd June, 1898 ..	Sheffield ..	Don ..	Attercliffe Steel Works .. (Sanderson Bros. & Co., Ltd.)	Stream at inlet to goit	23·2	4·8	18·4	very small			23·2	4·8	18·4	0·016	0·033	0·086	—
				Effluent from mill dam	626·7	177·5	449·2	592·3	167·2	425·1	34·4	10·3	24·1	0·036	—	3·104	—
23rd August, 1901	Todmorden	Walsden Water	Smithy Holme Mill .. (Starkey & Sons)	Discharge from dam	840·0	136·6	703·4	794·4	125·0	669·4	45·6	11·6	34·0	—	—	—	—
16th August, 1902	Sowerby ..	Ryburn	Thorpe Mill .. .. (F. E. Rawson)	Streamwater above	11·6	3·6	8·0	very small			11·6	3·6	8·0	0·002	0·008	0·024	0·11
				Discharge from dam	356·8	98·4	258·4	342·0	94·0	248·0	14·8	4·4	10·4	0·040	1·000	3·300	10·90

* Total Nitrogen.

Table XXIV.

Table showing Effect of Sewage and Effluents from the County Boroughs upon the Rivers.

The results are expressed in parts per 100,000. *All samples were taken after three dry days.*

Nature of Sample.	Time.	Solids in Suspension and Solution.			Solids in Suspension.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.		
	During hour commencing at	Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn).		Temp.	Perm.	Total.
Bradford, *May 3rd*, 1904.															
R. Aire, above junction of Bradford Beck -	8–0	4·14	19·26	23·40	0·14	0·46	0·60	2·20	0·10	0·055	0·016	0·30	2·2	12·6	14·8
Bradford Beck, near junction with R. Aire -	8–0	77·00	135·00	212·00	38·00	12·00	50·00	14·00	Nil	1·923	0·981	12·96	13·3	19·6	32·9
Effluent from Shipley Sewage Works - -	8–25	11·80	39·40	51·20	0·80	0·40	1·20	8·00	1·00	0·282	0·065	0·72			
R. Aire, below junction of Bradford Beck -	8–25	16·00	43·00	59·00	5·00	3·00	8·00	7·00	Nil	0·441	0·160	1·16	3·2	16·4	19·6
R. Aire, above junction of Bradford Beck -	4–0	8·06	16·58	24·64	0·06	0·58	0·64	2·75	0·08	0·045	0·025	0·32	9·0	7·4	16·4
Bradford Beck, near junction with R. Aire -	4–0	67·70	128·30	196·00	26·70	8·30	35·00	21·00	Nil	1·824	0·850	13·84	10·0	22·9	32·9
Effluent from Shipley Sewage Works - -	4–22	12·34	36·38	48·72	0·34	0·38	0·72	7·50	1·00	0·160	0·080	0·42			
R. Aire, below junction of Bradford Beck -	4–22	23·92	55·88	79·80	8·92	3·88	12·80	8·00	Nil	0·706	0·260	4·52	2·4	18·8	21·2
Halifax, *April 13th*, 1904.															
R. Calder, above junction of Hebble Brook -	8–0	5·48	11·52	17·00	0·48	0·52	1·00	3·25	0·16	0·050	0·028	0·27	0·7	6·0	6·7
Hebble Brook, near junction with R. Calder	8–0	11·88	34·44	46·32	4·88	3·44	8·32	5·25	0·10	0·504	0·090	1·43	0·7	13·3	14·0
R. Calder, below junction of Hebble Brook -	8–15	6·68	12·52	19·20	0·68	0·52	1·20	3·25	0·14	0·075	0·033	0·37	0·7	6·0	6·7
R. Calder above junction of Hebble Brook -	4–0	5·80	12·68	18·48	0·80	0·68	1·48	2·75	0·10	0·065	0·037	0·48	0·7	6·7	7·4
Hebble Brook, near junction with R. Calder	4–0	32·00	48·20	80·20	9·40	6·20	15·60	9·75	Nil	1·720	0·520	6·58	1·5	13·3	14·8
R. Calder, below junction of Hebble Brook -	4–15	6·76	15·92	22·68	0·76	1·92	2·68	3·50	0·09	0·181	0·082	0·75	Nil	7·4	7·4

TABLE XXIV. (*continued*).

Nature of Sample.	Time. During hour commencing at	Solids in Suspension and Solution. Loss on Ignition.	Ash.	Total.	Solids in Suspension. Loss on Ignition.	Ash.	Total.	Chlorides (as Na Cl).	Nitrogen. Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn).	Oxygen absorbed in 4 hours at 80° F.	Hardness. Temp.	Perm.	Total.
HALIFAX, *July 20th, 1904.*															
R. Calder, above junction of Hebble Brook -	8–0	3·88	18·20	22·08	0·68	1·00	1·68	4·00	Nil	0·261	0·043	0·49	0·7	7·4	8·1
Hebble Brook, near junction with R. Calder -	8–0	28·00	64·00	92·00	19·00	20·00	39·00	13·00	Nil	2·164	0·450	6·44			
R. Calder, below junction of Hebble Brook -	8–15	7·20	22·56	29·76	2·00	2·96	4·96	5·00	Nil	0·454	0·085	0·92	2·2	7·4	9·6
R. Calder, above junction of Hebble Brook -	4–0	5·48	20·40	25·88	1·08	0·80	1·88	4·00	Nil	0·218	0·063	0·76	1·4	6·7	8·1
Hebble Brook, near junction with R. Calder -	4–0	41·40	78·40	119·80	28·00	23·00	51·00	14·50	Nil	2·512	0·564	9·34	8·3	8·9	17·2
R. Calder, below junction of Hebble Brook -	4–15	11·80	28·20	40·00	4·40	5·00	9·40	5·00	Nil	0·408	0·124	1·95	2·9	7·4	10·3
HUDDERSFIELD (DEIGHTON), *March 4th, 1904.*															
R. Colne, above Sewage Works - - -	8–50	6·80	26·24	33·04	2·40	2·24	4·64	4·25	0·14	0·052	0·033	0·64	3·0	9·6	12·6
Storm Water overflow - - - - -	8–45	39·00	92·00	131·00	27·00	14·00	41·00	30·00	Nil	1·780	0·540	11·36			
Effluent from Sewage Works - - -	9–0	12·20	53·00	65·20	3·20	2·00	5·20	7·50	0·12	1·680	0·180	3·50			
R. Colne, below Sewage Works - - -	8–30	8·16	30·40	38·56	2·16	1·60	3·76	6·00	0·22	0·202	0·045	1·06	3·0	11·8	14·8
R. Colne, above Sewage Works - - -	4–0	7·12	27·84	34·96	3·12	2·24	5·36	4·00	0·14	0·083	0·064	0·97	3·0	9·6	12·6
Storm Water overflow - - - - -	4–5	45·00	91·00	136·00	33·00	17·0	50·00	23·20	Nil	1·930	0·560	11·28			
Effluent from Sewage Works - - -	4–15	19·40	81·60	101·00	8·40	3·60	12·00	24·50	Nil	1·670	0·328	5·50			
R. Colne, below Sewage Works - - -	3–50	9·44	31·36	40·80	3·44	2·16	5·60	7·00	0·18	0·220	0·076	1·46	3·0	10·3	13·3
HUDDERSFIELD (DEIGHTON), *July 14th, 1904.*															
R. Colne, above Sewage Works - - -	8–30	10·00	36·50	46·50	2·00	2·50	4·50	5·50	Nil	0·200	0·070	1·18	0·7	12·6	13·3
Storm Water Overflow - - - - -	8–30	46·60	104·40	151·00	35·60	23·40	59·00	43·00	Nil	1·510	0·750	15·84			
Effluent from Sewage Works - - -	8–30	17·00	66·00	83·00	10·00	9·00	19·00	23·00	Nil	1·060	0·240	7·08			
R. Colne, below Sewage Works - - -	9–20	14·00	46·00	60·00	6·00	8·00	14·00	9·00	Nil	0·490	0·180	2·82	3·0	11·8	14·8

R. Colne, above Sewage Works	4–0	11·48	50·76	62·24	1·28	1·76	3·04	7·00	Nil	0·260	0·060	1·32	2·4	16·4	18·8
Storm Water overflow	4–0	44·60	98·40	143·00	30·60	13·40	44·00	31·00	Nil	1·310	0·580	13·16			
Effluent from Sewage Works	4–0	20·80	89·80	110·60	10·80	6·80	17·60	24·50	Nil	1·660	0·320	8·92			
R. Colne, below Sewage Works	4–35	17·28	67·12	84·40	3·28	3·12	6·40	10·50	Nil	0·680	0·130	3·27	3·9	21·2	25·1
LEEDS (KNOSTROP), *March 9th*, 1904.															
R. Aire, above Sewage Works	10–20	8·20	34·20	42·40	1·20	3·20	4·40	4·75	0·10	0·170	0·060	0·84	4·0	14·8	18·8
Effluent from Sewage Works	10–35	23·00	90·00	113·00	10·00	8·00	18·00	20·75	Nil	1·860	0·480	5·64			
R. Aire, below Sewage Works	10–45	11·52	57·28	68·80	3·52	3·28	6·80	8·25	Nil	0·490	0·190	1·66	5·6	15·6	21·2
R. Aire, above Sewage Works	3–30	11·04	29·96	41·00	3·04	2·96	6·00	4·00	0·13	0·120	0·060	0·98	6·2	11·8	18·0
Effluent from Sewage Works	3–45	28·00	84·40	112·40	10·00	4·40	14·40	24·50	Nil	3·040	0·400	5·72			
R. Aire below Sewage Works	3–55	10·04	39·56	49·60	3·04	2·56	5·60	7·50	Nil	0·656	0·120	1·58	6·3	13·3	19·6
LEEDS (KNOSTROP), *August 10th*, 1904.															
R. Aire, above Sewage Works	10–0	12·92	53·40	66·32	1·92	2·40	4·32	9·00	Nil	0·86	0·11	1·78	7·9	13·3	21·2
Effluent from Sewage Works	10–20	18·16	93·60	111·76	4·16	5·60	9·76	31·00	Nil	2·16	0·23	6·18			
R. Aire, below Sewage Works	10–30	20·44	84·96	105·40	9·44	10·96	20·40	21·00	Nil	1·47	0·25	5·34	13·3	19·6	32·9
R. Aire, above Sewage Works	3–30	16·80	62·70	79·50	6·80	9·70	16·50	7·75	Nil	0·82	0·17	2·84	4·8	16·4	21·2
Effluent from Sewage Works	3–50	32·60	91·40	124·00	17·60	6·40	24·00	20·00	Nil	3·70	0·69	12·08			
R. Aire, below Sewage Works	4–0	35·60	90·40	126·00	19·60	9·40	29·00	18·50	Nil	3·65	0·61	10·40	14·9	18·0	32·9
ROTHERHAM, *May 3rd*, 1904.															
R. Don, above Sewage Works	8–50	9·60	58·60	68·20	0·60	0·60	1·20	17·00	0·08	0·550	0·050	0·50	8·7	16·4	25·1
Effluent from Sewage Works	8–50	17·56	56·40	73·96	2·56	0·40	2·96	15·00	0·12	1·900	0·090	0·92			
R. Don, below Sewage Works	8–50	17·80	69·20	87·00	4·80	3·20	8·00	25·00	0·10	0·540	0·050	0·90	8·6	18·0	26·6
R. Don, above Sewage Works	3–50	10·28	58·92	69·20	0·28	0·92	1·20	17·50	0·10	0·460	0·060	0·54	8·7	16·4	25·1
Effluent from Sewage Works	3–50	14·78	51·82	66·60	0·78	0·82	1·60	14·50	0·18	1·430	0·090	0·84			
R. Don, below Sewage Works	3–50	13·04	64·36	77·40	2·04	2·36	4·40	21·50	0·10	0·440	0·070	0·72	7·1	18·0	25·1

TABLE XXIV.—*continued.*

Nature of Sample.	Time.	Total of Solids in Suspension and Solution.			Solids in Suspension only.			Chlorides (as Na Cl).	Nitrogen.			Oxygen absorbed in 4 hours at 80° F.	Hardness.		
	During hour commencing at	Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.		Nitric.	Ammoniacal (from Free and Saline Amm.)	Alb. (Wanklyn).		Temp.	Perm.	Total.
ROTHERHAM, *July 21st*, 1904.															
R. Don, above Sewage Works - - -	10–30	13·52	86·88	100·40	1·52	0·88	2·40	38·00	Nil	0·931	0·120	1·16	Nil	26·6	26·6
Effluent from Sewage Works - - -	10–30	11·40	54·20	65·60	2·40	1·20	3·60	14·50	Trace	1·786	0·176				
R. Don, below Sewage Works - - -	10–30	12·68	101·84	114·52	2·08	1·44	3·52	49·00	Nil	0·990	0·120	1·29	Nil	26·6	26·6
R. Don, above Sewage Works - - -	4–0	14·84	81·96	96·80	1·84	0·96	2·80	36·00	Nil	1·234	0·140	1·76	3·0	25·1	28·1
Effluent from Sewage Works - - -	4–0	13·60	49·12	62·72	1·60	1·12	2·72	15·00	0·14	1·588	0·126	1·42			
R. Don below Sewage Works - - -	4–0	18·80	103·36	122·16	2·80	1·36	4·16	56·00	Nil	1·120	0·130	1·98	9·3	25·1	34·4
SHEFFIELD, *May 12th*, 1904.															
R. Don, above Sewage Works - - -	9–40	8·00	27·00	35·00	very small			4·00	0·10	0·050.	0·010	0·14	0·8	11·0	11·8
Effluent from Sewage Works - - -	9–40	20·00	49·40	69·40	2·00	1·40	3·40	16·75	Nil	1·250	0·160	3·60			
R. Don, below Sewage Works - - -	9–40	10·40	37·60	48·00	2·40	1·60	4·00	7·00	Nil	0·870	0·160	1·33	Nil	14·8	14·8
R. Don, above Sewage Works - - -	4–0	5·40	28·20	33·60	very small			4·00	0·11	0·040	0·010	0·12	9·4	11·0	20·4
Effluent from Sewage Works - - -	4–0	28·76	60·64	89·40	6·96	3·04	10·00	19·50	Nil	3·480	0·550	6·24			
R. Don, below Sewage Works - - -	4–0	8·92	31·92	40·84	0·92	1·52	2·44	6·50	0·07	0·290	0·040	0·85	1·6	11·0	12·6
SHEFFIELD, *July 19th*, 1904.															
R. Don, above Sewage Works - - -	10–0	10·24	43·96	54·20	0·24	1·16	1·40	6·50	Trace	0·095	0·020	0·34	2·3	13·3	15·6
Effluent from Sewage Works - - -	10–0	12·00	47·08	59·08	2·40	1·48	3·88	13·00	Nil	1·302	0·120	1·20			
R. Don, below Sewage Works - - -	10–0	8·64	43·76	52·40	1·04	1·76	2·80	7·75	Nil	0·429	0·050	0·60	1·5	14·1	15·6
R. Don, above Sewage Works - - -	4–0	6·90	40·20	47·10	0·40	1·20	1·60	5·75	0·02	0·138	0·023	0·42	2·3	13·3	15·6
Effluent from Sewage Works - - -	4–0	22·00	72·50	94·50	9·00	3·50	12·50	26·50	Nil	4·516	0·648	5·56			
R. Don, below Sewage Works - - -	4–0	19·50	63·00	82·50	5·50	3·00	8·50	21·50	Nil	2·972	0·372	4·00	8·1	14·8	22·9

ROYAL COMMISSION ON SEWAGE DISPOSAL.

APPENDIX TO DR. H. MACLEAN WILSON'S EVIDENCE.

WEST RIDING OF YORKSHIRE.

REFERENCE

County Boroughs	shown thus ...	HALIFAX
Non-County Boroughs	„ ...	BARNSLEY
Urban Districts	„ ...	BINGLEY
Rural Districts and Parishes	„ ...	SETTLE SETTLE MALHAM
Watersheds	„ ...	---------

Points at which Quarterly Samples have been taken.

1. Aire at Stockbridge.
2. Aire at Saltaire.
3. Aire at Apperley Bridge.
4. Aire at Methley.
5. Bradford Beck.
6. Hol Beck.
7. Calder at Hebden Bridge.
8. Calder at Cooper Bridge.
9. Calder at Thornes Bridge.
10. Calder junction with Aire.
11. Colne junction with Calder.
12. Dewsbury Beck.
13. Hebble Brook.
14. Spen Beck.
15. Don at Wortley.
16. Don at Kilnhurst.
17. Don at Conisbrough.
18. Tame at Mossley.
19. Wharfe at Addingham.
20. Wharfe at Pool.

SCALE
4 ENGLISH MILES TO 1 INCH

HELIOZINCOGRAPHED AT THE ORDNANCE SURVEY OFFICE, SOUTHAMPTON, 1905.

23916. In your statement on dam sludging, you say that since the decision in the High Court there have been bitter complaints by manufacturers. I presume that since that case there have been no more appeals to the courts of law ?—We have had two appeals, one in 1899, I believe it was, and one last year ; we have not taken any case since then.

23917. And what was the result of those cases ?—They were both dismissed in the High Court.

23918. Do you consider that the law ought to be altered so as to give power to deal with the evils of sludging mill dams, and if so, what alteration of the law do you recommend ?—Most certainly the law ought to be altered ; it was fully intended in the 1894 River Boards Act that dam sludging should be stopped altogether ; that is very evident from the proceedings which took place before the Parliamentary Committee ; and it is only by this ruling of the court—which is evidently, from those proceedings, not in accordance with the intention of the Act—that we have been prevented stopping dam sludging.

23919. (*Mr. Power.*) Do you say stopped altogether ; was there no alternative or was there an alternative prescribed by the Rivers Board ?—It was stopped altogether ; there is no necessity for dam sludging and the flushing out of mud as it accumulates in the dams ; they can remove it by other means.

23920. By other means ?—Oh, yes.

23921. Other than the practice of pushing the sludge into the stream, leaving the stream to carry it away ?—That should be prohibited.

23922. (*Colonel Harding.*) Of course, your view, Dr. Wilson, is that where the manufacturer dams a stream for his own benefit he incurs the responsibility of any damage that he may cause thereby ?—Yes.

23923. But were you able in the cases you refer to, to prove that there was actual damage in the case of an unpolluted stream ?—We did not prove that there was any pecuniary damage but we proved the bad effect upon the stream, that is, the deposit of sludge in the bed of the stream and the utter spoiling of the water while the sludging was going on.

23924. And that would last how long, a day or two ?—Yes, a large dam always takes a few days in being cleaned out in that way.

23925. And the evil was almost wholly due to the exceptional quantity of suspended matter coming down in the stream ?—Yes, of which you have analyses in the table.

23926. In the table you have handed over to us ?—In Table XXIII. there is an analysis of waters of the streams while sludging was proceeding.

23927. Yes, I notice the amount of albuminoid ammonia rose to from ·008 to 1·0 ?—Yes, that was in one of the cases that we took.

23928. Can you tell us how that case was lost ; was it due to the failure to prove pollution ; or was it due to the saving clause which apparently permits a manufacturer to let off from his dam natural deposit which was brought to him by the stream ?—Well, as far as I understood the judgment it was on the ground that, although it was admitted that some hundreds of tons of sludge were flushed out of the dam into the stream, it was so diluted with water before it reached the stream that it was not sludge, and therefore the defendant was found not guilty of putting sludge into the stream. It is a very legal argument, but that was what I understood the judgment to be, that he flushed out the sludge, so diluted with water that it was no longer sludge when it reached the stream.

23929. But you brought evidence to show the enormous increase of suspended matter at the time, did you not ?—Yes, these analyses were before the court.

23930. The powers of the Mersey and Irwell Standing Joint Committee are greater than yours, are they not in reference to that ?—I think not.

23931. Mr. Tatton gave evidence before us and said that their Act was somewhat stronger and that they had been able in effect to stop dam sludging ?—I believe it is because their cases have not been appealed against.

23932. But their Act is somewhat stronger than the Rivers Pollution Act of 1876, is it not ?—And our Act was supposed to be stronger than the Rivers Pollution Act of 1876, but it has not proved so.

23933. How are you able to account for their success and the failure of the West Riding Board in these prosecutions ?—I believe it is because the cases have not been fought as our cases have been fought.

23934. Of course, the case of a polluted stream is very different ; the sludging of dams on a polluted stream is a very much more serious evil than the sludging of dams into an unpolluted stream ?—It may or it may not be ; it depends on the use of the water by the riparian owners below. Even with an unpolluted stream the actual pollution caused by the sludging of the dams is very serious. If a manufacturer below is using the water for any particular purpose the result of the damage may be quite as great if not greater, because he may need to use perfectly clean water ; but while the dam sludging is going on it is unusable for any of his purposes.

23935. As a fact you have had repeatedly on your Board serious complaints of the evils of dam sludging, have you not ?—Oh, yes, repeated complaints.

23936. And bitter complaints ?—And bitter complaints.

23937. The mere flushing of dams you do not appear to lay much stress upon ; you think if it were done under certain regulations as to the time when the flushing should take place, that is not so serious a matter ?—I think that might be looked upon as a legitimate thing.

23938. In regard to the sludging you express a strong opinion that the sludging of mill dams by stirring up the sludge in the dam and letting it go into the stream ought not to be permitted at all ?—It should be prohibited.

23939. What is the alternative if that is to be prohibited. The alternative apparently is to draw off the water and then barrow out the sludge and deposit it on the lands somewhere in the neighbourhood ?—Yes.

23940. The question turns upon the financial practicability of doing that ?—I think, if I may say so, that on the whole that is the more common practice in the West Riding.

23941. I was coming to that. You have found in practice that in your district, that is in the West Riding, that is the general practice ?—Yes.

23942. And therefore you have no hesitation in expressing the opinion that it is quite practicable financially to do it ?—Certainly.

23943. Seeing that it is done by a large number of manufacturers ?—Yes.

23944. And all you want is to have the law so modified as to compel those who do not do it to carry out the same process as is already carried out by many manufacturers ?—Yes.

23945. But there are exceptional cases, are there not, where it would be very costly to carry out the removal of the sludge by barrowing or carting ?—There are certainly. In some cases where the dams are in narrow valleys and on the streams as a great many of our dams are it would be costly.

23946. Is it practicable at all in many cases ?—I do not know anywhere where it would not be practicable, but the difficulties add to the cost.

23947. It would be much more expensive ?—Yes, the difficulty of the situation often adds greatly to the cost. But I may give you the most extreme instance we have had. In the town of Bradford there is a very large dam ; and the manufacturer was prosecuted some ten years or more ago for sludging this dam down the stream. It caused a great nuisance, because in that case he happened to discharge his own trade refuse into the dam and the sludge was most offensive and putrid. He has cleaned it out since then by barrowing, and I must say at very great expense, very great expense because it is in the middle of the town ; he had to put the sludge into trucks and carry it away ; but that is the most extreme case I know.

23948. And in that case it was done ?—It was done.

Mr. H. Maclean Wilson.

16 May, 1906.

23949. In that case you had ample powers because he was turning his own trade pollution into the dam?—Yes.

23950. That gave you an exceptional condition which permitted you to bring pressure upon him?—It was obviously not sludge which had been wholly brought to him by the current of the stream. That is one of the exemptions under our Act.

23951. The whole matter turns upon the financial practicability of removing this sludge. You say without hesitation that in a great many cases in the West Riding that has actually been done, and has been done for some years by manufacturers, and all that you want is that it should be done by all?—That is so. If you will allow me I will put in some photographs, which will show very clearly, I think, the two ways of doing it. This is the case of the Wortley Rural District (*indicating photograph*). We have a photograph of the men actually engaged pushing the sludge with spades into the current of the water turned through the dam. As I have described, the stream is turned wholly through the dam and the men push the sludge in with spades and shovels or barrow it in as in this case. And that is the point of discharge. (*Photographs handed in.*)

23952. The photographs are interesting, but I think we quite appreciate the way in which the work is being carried out?—That is the other way of doing it, by barrowing it out. (*Photograph handed in.*)

23953. Now, in your evidence you say, "That the prohibition of the practice was expressly sought, and after strenuous opposition granted by Parliament, but the courts have upset that in the two West Riding cases." What is your authority for that statement?—That it was granted by Parliament?

23954. Yes, and that the matter was strenuously fought out and opposed before Parliament?—That is very evident from the report of the Parliamentary proceedings and the discussions upon the Bill before the Parliamentary Committees. There was a strong opposition on the part of the manufacturers to this attempt to prevent the sludging of mill dams, but they were defeated; and as is very apparent from the Parliamentary proceedings it was obviously intended by Parliament to stop the practice altogether.

23955. Then what was the clause inserted which leads you to think that that was the intention of Parliament?—It is definitely stated in the Act that the sludge from mill dams is not to be put into the streams. Have you a copy of the Act?

23956. On the other hand there is a saving clause, is there not?—There is a saving clause to the effect, speaking from memory, that any deposit which has been brought by the natural current of the stream may be put back if it causes neither pollution nor obstruction. But I think it is very evident from the Parliamentary proceedings that that saving clause was not meant to affect the question of dam sludging at all. It was meant to deal with the deposit of sand or gravel or similar material brought down by a flood and deposited on the land. It was contended that it is the usual practice to clear a field of sand or gravel that has been deposited by a flood and put it back into the bed of the stream.

23957. Anyway the Act in its present form is not sufficiently strong to enable you to prevent what you consider to be a serious nuisance?—I think not.

23958. And you think it ought to be modified accordingly?—Yes.

23959. I wish to ask—probably you will not approve of the suggestion, but I will make it in order to get your view upon it—whether since local authorities are interested in the purification of the streams, the deposition of matters in mill dams of a polluted stream could not be made useful if the sediment was removed on to lands; if so, could not the local authority be properly called upon to contribute towards the cost of removing the deposited matter from dams in polluted streams?—I think not, sir, for these reasons. The Commission is fully aware of the immense difficulty of getting rid of the sludge from sewage works, which certainly would be a richer sludge in nitrogenous matters than the sludge in mill dams or in streams; and the deposit in these mill dams or streams being almost wholly due to the action of the manufacturer or the owner of the mill dam, it seems to me, if I may say so, unreasonable to call upon the sanitary authority to help pay for the removal of that sludge.

23960. It was suggested to us that the manufacturer is really carrying out what would be a harmless process if the stream were not polluted, and that the manufacturer is not responsible for the pollutions; therefore, it occurs to one to suggest that it might be to the interest of the local authorities to look upon the settlement of mill dams as a sort of sewage disposal process, a useful process?—I do not think so; it does not seem reasonable to me to call upon the sanitary authority to pay for that,

23961. (*Sir William Ramsay.*) May I instance a similar case where something of that sort was done. The Clyde Trust had to dredge the Clyde and they asked leave of Lord Glasgow to be allowed to tip their rubbish dredges on his land; he refused. They then took it down in barges, and emptied it into the estuary of the Clyde. At a later date he withdrew his refusal, but he charged them, I think, a farthing a load for allowing them to put it on his land. The result is that he gained enormously by it;—not merely in making the farthing a load, but in having an enormous amount of land which was quite useless reclaimed. You may look upon Lord Glasgow as the sanitary authority and the Clyde Trustees as the people who have refuse for disposal. In some cases it would be to the advantage of the sanitary authority to have land made?—Very rarely so, because the sanitary authorities very seldom possess any land on which to deposit it. They have great difficulty in finding a deposit for their own refuse as a rule.

23962. (*Colonel Harding.*) The only thing is that you get as an incident in connection with these mill dams a deposit of matter, the removal of which from the streams is exceedingly desirable in the general interest?—Yes, that is so.

23963. And the manufacturer who impounds the stream claims that he is not personally responsible for the polluted condition of the stream; and, therefore, it would seem at first sight as if it were in the general interest that this matter should be removed from the stream, and if so, that the whole cost should not fall upon the manufacturer. I take it that your view is that it is not practicable?—I have not considered that closely. I think that in certain cases especially it would be greatly to the general advantage if the sanitary authority itself cleaned out, and in many cases channelled the streams, as has been done in some of the smaller streams in Leeds, charging the cost either partially or wholly upon the inhabitants generally or upon the manufacturers who benefit in particular. That would amount in some degree to what you are suggesting. I have in view now some of the streams in Leeds and the other big towns, more especially the Batley Beck.

23964. Then I understand that you think the point is any way worth considering?—Yes, in connection with some of these very foul streams in the close and thickly inhabited districts.

23965. (*Mr. Power.*) Do you think the charge should be a special one on the riparian proprietors of land on the stream, or only upon those of them who are manufacturers and get rid of their refuse in the stream?—I believe that at present the sanitary authority can call upon the riparian owners in the case of a polluted stream which is in such a state as to cause a nuisance. They can call upon the riparian owners to clean that out, and if the riparian owners do not do it I believe that the sanitary authority can do it and charge them with the cost.

23966. It is the extension of that principle that you are thinking of?—Yes, but in such places as I am mentioning now it would be to the advantage of the district as a whole.

23967. You think that it might come partly upon the ratepayers and partly upon the riparian owners and partly on the manufacturers whose special pollution brought it about?—Yes.

23968. It would be on a different scale in each of those instances?—Yes.

23969. (*Mr. Stafford.*) You have given us the opinions of the Rivers Board; but could you give us the point of view of the owners in this question—the owners who are resisting, the mill owners?—I can, of course, give you the

views that they put forward in Court and before the Parliamentary Committee.

23970. Yes ?—That it is solely a question of cost.

23971. But you do not seem to think that the cost is prohibitive ?—No.

23972. Do they consider it prohibitive ?—They say so.

23973. In other words it would ruin their business ?—They say so.

23974. That is a very serious question ?—That is a very serious question, but I think we very plainly showed before the Parliamentary Committee—and it is very evident I think from the fact that so many of the dam-owners use the other method of cleansing their dams, that the cost of doing so is not prohibitive.

23975. But you say also that it is perhaps in the easy cases that they cleanse their dams. You admit that there are a great many difficult cases in which the cost would be very large; would it ruin these men, or practically ruin them, or largely interfere with their trade in these difficult cases; because if it would it is a very serious question ?—I do not think so. I have given what I think is the most difficult case I know of in the West Riding where the dam actually has been cleaned out by barrowing.

23976. Was the cost what you might regard as prohibitive there ?—I think not, considering the magnitude of their business.

23977. But they evidently impressed the Parliamentary Committee very strongly that they had a strong case ?—They did not convince the Parliamentary Committee.

23978. No ?—To be perfectly fair, I should like to say that in the case of some of these smaller mills where they have large dams which require cleaning out, the cost may be a very serious thing in comparison with the business, because the value of water power in the West Riding has diminished enormously; in all big mills, in the vast majority of mills, of course, they have had recourse to steam or electric power, and the value of water power is of very little moment comparatively; so that if you take a small business which happens to have a big wheel and a large dam, the cost may be a very serious thing in that particular case.

23979. Now, what would you propose to do in that case; what would you propose to do in cases of that kind, where the cost was really going to interfere with the trade of the individual; perhaps to drive him from his business ?—Well, I have not come across such an extreme case as that; and one point upon which I am very strong is that the owner of the mill dam by adopting proper means, can, to a very great extent indeed, prevent his dam from getting silted up. It is due in the first instance chiefly to his own gross carelessness that the silt gathers in his dam, although he must clean his dam sometimes.

23980. It must silt up to a certain degree ?—Yes.

23981. It must be in his dam sometimes; it must silt up ?—But it would not be for a very long period if he adopted proper means for preventing it.

23982. Proper means—would they mean much in the way of cost ?—No. He should provide a catch pit before the water of the stream reaches his dam and clean that out after storm times; that is done in many cases.

23983. Would you admit that there are certain cases in which it would be a very serious handicap to certain mill-owners who are badly circumstanced on the rivers, to make them clean out their dams in the way you suggest ?—There are a few cases, but they are of very small moment compared to the immense benefit which would accrue to the streams by stopping the practice.

23984. What do you do in these exceptional cases ?—I am afraid the individual must suffer, as happens with all laws. The suffering to him would be very small indeed compared to the benefit that would follow to the others on the same stream.

23985. So that you would not really think that it would be a serious question to interfere with trade; that it would not be a serious trade question to drive these people out of the country ?—It does not amount to that at all. The interference would be very slight indeed and the number of cases very few.

23986. But there might be some means of compensating them ?—I have not thought that out; I do not know whether that could be done or not; it opens a very wide question if you are going to compensate every mill dam owner.

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23987. Not every mill dam owner; you acknowledge that the cases are exceptional; but in the cases where you kill the trade or injure the trade of an individual, might there not be some means of compensating him ?—Well, the damage that he does by this practice is so great compared with the cost that he would be at in stopping the practice, and the cases of hardship are so few, that I do not think they are seriously worth considering in that way.

23988. (*Mr. Power.*) In the particular instance that you mentioned, did the manufacturer bear the whole cost of those expensive sludgings ?—Yes.

23989. And they were frequent sludgings, were they not ? They do not bear any comparison to the small wheel you were speaking of with low water power and a large dam ?—No.

23990. They would not be very frequent sludgings then ?—No, not frequent.

23991. Would it be once a year ?—This was done about ten years ago when proceedings were taken, and it has been done once since only some three or four years ago.

23992. It had to be not only removed in barrows but put into carts and taken outside the town ?—Yes.

23993. (*Chairman.*) Passing on to the question of standards, I am not quite certain whether I quite correctly understand the third paragraph of your note. Do I understand you to mean that all streams ought to be rendered free from any nuisance and fit for any possible purpose except that of domestic water supply, and that as long as the streams get into that condition you are indifferent as to whether the sewage going into it requires simple or elaborate treatment ?—Yes, it amounts to that; if we get the stream like that we would have no cause of complaint.

23994. For instance, if the sewage is weak, and the stream is large, you would not require that sewage to be treated as carefully as a large amount of strong sewage going into a small stream ?—I think I should not advise the Rivers Board to take proceedings in a case of that kind unless we could point to definite damage of the stream.

23995. I mean obviously there would be a waste of money in requiring the same treatment to all sewage ?—Yes.

23996. You quite agree with that ?—Yes, I agree with that.

23997. (*Colonel Harding.*) On the other hand, you would not allow the polluted condition of a stream to become a reason for relaxing the standard ?—Not at all; that is what I have tried to state. Perhaps I have not stated it very clearly, but the standard must surely not be settled with regard to the present condition of the streams, because, as I have pointed out, we have, for instance, in the case of the river Aire a grossly polluted stream, perhaps the most polluted in the kingdom. But the number of pollutions are now comparatively few and there is no reason why it should not be a clean stream.

23998. You do not see any prospect of improvement if the polluted condition of a stream is to be made an excuse for a relaxed standard ?—Certainly not, that would stop all improvement.

23999. On the other hand, you can conceive of cases where there is a stream practically unpolluted, of large volume but into which a relatively small pollution is poured, the effect of which is scarcely appreciable. You can conceive of such a case as that ?—Yes.

24000. In such a case you would not think it advisable to prosecute an authority, or to compel an authority to spend a large sum to remove such pollution, would you ?—I think that needs to be looked at in two ways. Of course, in the first instance, all our streams in the West Riding were in that condition, and if the beginnings of pollutions are not stopped, then the streams which are now clean may get as bad as the more polluted ones; so it is necessary, I think, in the case of these clean streams, to prevent pollutions being poured into them.

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24001. You think probably if that course had been followed in the first instance in connection with the unfortunate river Aire that it would never have reached the filthy state that it is in now?—That is so.

24002. But as you are aware, there are very numerous cases in the West Riding of clean streams which are of considerable volume, where the villages of some considerable size still pour their sewage untreated into the rivers, and the Rivers Board have not seen fit to take any action?—Because the effects are so slight.

24003. While in theory you think it ought to be aimed at in every case to produce effluents which are not liable to putrefaction, a discretion must be left with the Rivers Board or the supervising authorities?—With the law courts over them to decide.

24004. You would not consider it the duty of your Board to take action in a case where the pollution turned into a stream did not have any appreciable evil effect?—They have never yet done so.

24005. But you see the great importance of watching the beginnings of pollution to prevent the gradual deterioration of a stream?—Yes, and if I may say so, I think one great good that the Rivers Board has effected has been in stopping the pollution of our clean streams, such as the Wharfe, in which practically all the pollution is stopped now, whereas the stream was going from bad to worse. If the pollution had been allowed to increase in the Wharfe valley as it has in the Aire and Calder valleys, then the Wharfe might in years to come have been as bad as the Aire and the Calder.

24006. As a matter of administration you consider it extremely difficult for your Board to make any difference in the standard of purification required either in different parts of the stream or in different streams in your district, because of the natural jealousy which would arise between the local authorities if you did that?—That is so. I think it is impracticable; I have thought it over and over.

24007. And in the interests of river purification you think it far better to deal substantially in same way with all cases, the object being to prevent the pollution of streams?—Yes; you know, of course, my own view is that however desirable the standard might be for working the Rivers Pollution Prevention Acts, I do not see how it is practicable, and I think we must still fall back upon the use of the best reasonably available means. I should be glad for the sake of my own work to have a definite standard in all cases to work to; it would render my work easier, but I have never seen how it is practicable.

24008. Anything in the way of a varying standard you think inadvisable?—I think in the West Riding it is utterly impracticable.

24009. You have put before the Commission a series of tables which appear to me to be of great interest; they enable us to form an opinion as to the condition of your more important streams. Of those the River Aire seems by far the worst?—I think the Calder runs it very close.

24010. I was rather struck with the difference between the Calder and the Aire; the Calder seems much better?—The Aire is the worst.

24011. Now, the tables throw a certain light upon the self-purification powers of rivers and streams. One is struck, for instance, to find at Saltaire you have certain pollutions from Keighley and other places which have sewage works in operation, I suppose?—Yes.

24012. Yet there are fish in the stream above the Bradford Beck?—That is so.

24013. And you go so far as to say there is trout?—Yes, there is a fishing club which fishes down to Saltaire.

24014. But the flow from Bradford Beck, which is extremely foul, alters the whole character of the river?—Yes.

24015. Do you happen to know roughly what is the relative volume of the Bradford Beck to the stream of the Aire at the junction?—I am sorry I have not that. I have made enquiries several times, but I have not got it.

24016. You are unable to express even a general opinion—whether it would be 1 to 4 or anything of that kind?—It is more than that; it would be perhaps 1 to 10.

24017. The Aire ordinary flow would be ten times the volume of the Bradford Beck?—I should say so.

24018. In your table as to the condition of the Bradford Beck I see that the solids in suspension are actually 65 parts per 100,000?—Yes.

24019. And the albuminoid ammonia by the Wanklyn test is ·98, or substantially 1 part per 100,000?—The solids in suspension—

24020. Are 65; I am taking the average at the bottom of the page?—Yes.

24021. The albuminoid ammonia is substantially 1 part per 100,000?—Yes.

24022. And the oxygen absorbed is 12½?—Yes.

24023. That is quite as bad, or indeed worse, than the average sewage, is it not?—It is.

24024. What is the effect of that upon the river Aire, if we take your analyses of the Aire at Apperley?—Comparing the one at Saltaire with the other at Apperley?

24025. You say that at Saltaire the condition is fair; it supports fish life?—Yes.

24026. But, after receiving the flow of the filthy Bradford Beck, we find at Apperley—which would be about four miles lower, I suppose, would it not?—Yes.

24027. The condition of the river, although very foul, does not seem to have been so seriously affected as one would expect by the flow of the Bradford Beck?—Well, I do not know. If you compare the albuminoid ammonia.

24028. I see the solids in suspension are 13 and the albuminoid ammonia to which you refer is ·23?—Yes, as against ·027.

24029. You are comparing it with Saltaire are you not?—Yes.

24030. There is considerable pollution, evidently?—There is ten times the amount of albuminoid ammonia.

24031. But if you compare that now with the analyses at Methley, you there see the condition of the river after that it has received in addition the whole sewage of Leeds?—Yes.

24032. And yet it is better than at Apperley?—That puzzled me for a long time.

24033. Can you explain it?—I think I can. I have noticed that time and again, as you are aware. I believe it is because the river below Leeds is turned into the canal, and a very great deal of deposition of solids, at least, and of putrefaction takes place in the river, both in the original river bed, which is robbed of its flow, and also in the canal, and I think a great deal of purification takes place there in ordinary times, and that in flood times a vast amount of deposited sludge is washed down the stream.

24034. But can this discharging part of the flow through the canal seriously affect it; it is simply a divided stream? Yes, but it is a stream with a very slow gradient, being in the canal; it is actually ponded up by locks and a great deal of deposition of sludge takes place.

24035. The fact remains that those analyses show considerable powers of self-purification in the stream?—I am not sure that they show that, there are a good many weirs on the stream—on the river Aire—behind which there is a great deposition of solids. So that you cannot altogether say that it is natural purification going on. It is a great deal due to the deposit of solid matters which lodge behind the weirs in dry weather and get washed down in floods.

24036. I was going to ask you whether this undoubted self purification which takes place is not at the expense of the unfortunate people who dwell on the banks of the stream. The stream receives the deposits and nearly all the suspended matter brought down to it, and in this particular district it becomes a septic tank for the treatment of impurities sent down to it?—That is exactly what happens.

24037. A sort of automatic sewage treatment?—Yes; the stream above these weirs, both between Bradford and Leeds and below Leeds, is a bubbling festering mass.

24038. So that we must consider the improvement in the river as having taken place at the expense of the populations dwelling on the banks?—Yes.

24039. The river having become really a septic tank ?—Yes, it is more an apparent improvement than a real improvement, because these solids are deposited in ordinary times to be flushed down in times of flood, and I have seen after a flood, as far down as the Gateforth Estate, the land adjoining the river covered with several inches of black fetid mud which has been washed out of the pools.

24040. Out of the septic tank ?—Yes.

24041. (*Mr. Power.*) Is there no dredging between the weirs in dry weather ?—No, not in the stream itself. Below Leeds, and between Leeds and Bradford, navigation goes on parallel with the river, in canal cuts, and not in the river bed itself, and there is no dredging of the river bed.

24042. (*Colonel Harding.*) I know how busy your staff is in connection with analyses, but it would be of real interest if you were able in your data about the river Aire to introduce an additional analysis of the waters immediately before the river Aire receives the sewage of Leeds ?—I can do that. (See Table XXIV., now added.)

24043. I think it would be exceedingly interesting, as you would then be able to judge exactly what was the effect of adding the sewage of Leeds ?—There is a complication there, if I may say so. There are a great many storm overflows within Leeds City, and in times of rainfall, at least, they would be discharging heavily.

24044. No doubt. I note your observation about the condition of the Aire and the prospects of improvement. It is very interesting to find that in your opinion the purification of the sewage of Bradford and Leeds would bring about an immediate improvement in the condition of the river ?—It would, I am certain of that.

24045. And you think it quite possible by the effective treatment of the sewage of Bradford and Leeds to bring the river into the condition in which it is at Saltaire ?—Practically so. There is now remaining very little pollution of the river Aire, except that from Bradford and Leeds—below Saltaire.

24046. Of course, there is a feeling of general hopelessness in the district, is there not, as to any improvement being brought about in the condition of the Aire ?—Yes, there is a feeling of distrust.

24047. But you do not share it ?—No.

24048. You foresee that when these two great corporations have carried out their work there will most certainly be a striking improvement in the condition of the river ? There is no doubt about it. Most of the other pollutions have been fairly well dealt with, or are being dealt with at present.

24049. (*Mr. Stafford.*) Are the people living on the banks of this canal as healthy as those in the other parts of the town, do you know ?—I am afraid there is very little actual proof of any detriment to health. The Medical Officers both of Leeds and Castleford and the neighbourhoods on the Aire below Leeds have stated that in their opinion it was detrimental to health.

24050. Have you made any comparisons between that particular part and other parts of Leeds ?—Yes, at one time I assisted the Medical Officer of Health for Leeds in getting out statistics of deaths from diarrhœa, comparing the population within half a mile of the river with the rest of the population in the town ; and there was a very great incidence of fatal diarrhœa in the population near the river.

24051. Would this be due possibly to the fact that the houses along the river were less healthy, generally speaking ?—I was going to add that any conclusions were rather confused by the fact that naturally the population in the low-lying part of the town along the river bank was not of the same status as the population on the higher grounds, so that it is difficult to draw any very definite conclusion.

24052. I am interested in this matter, because we have the same problem in Dublin—the people living on what is a septic tank—the Liffey ?—Yes.

24053. And there it is alleged that the river side is the healthiest part of the town ?—Oh !

24054. (*Colonel Harding.*) Quite apart from the condition of this river bringing about actual disease, do you not think it indirectly affects the people through the smells that it produces and the wretched appearance of the stream and the vegetation all round ?—I think it directly affects the health of the people, because it is impossible with any degree of comfort to keep a window open by the river there in the summer time.

24055. Would you consider the immediate neighbourhood of Kirkstall Bridge a desirable place to live in ?—I should require a very big salary to live in it. But I would go further and say that there are many houses on the Aire and on the Don that are empty—good houses—because of the smells from the stream. We have had complaints frequently from people living in large places on the latter stream, especially below Sheffield, where they say they cannot get servants to stay with them because of the smells ; they are so often ill from the smells from the river.

24056. It is notorious that there is a depreciation in the value of property near the banks of the river ?—No one would ever choose to live near one of these stinking rivers.

24057. And the purification of the stream would be a general benefit in that respect ?—Yes.

24058. (*Mr. Stafford.*) Do you think that living in the immediate neighbourhood of septic tanks is dangerous to health ?—Yes, anywhere within the radius of the smell would be deteriorating to health ; I am confident of that.

24059. (*Sir William Ramsay.*) I should like to ask you a question or two on these analyses ?—I do not know whether they are of any use, but I have some charts here with the analyses put on in graphic form.

24060. They are merely questions with regard to some of the figures. On Table III., "Analyses of Water of River Aire at Apperley Bridge," the results are very bad. Does the water stand the incubator test ?—I cannot remember whether we have ever tested it ; I am afraid not.

24061. It looks as if it would not ?—I should be confident it would not. In summer time it putrefies and lets off sulphuretted hydrogen to a very great extent.

24062. Was there any dam sludging on the 6th September, 1901 ; it was fearfully bad, going up to 277 parts of solids in suspension and solution ?—No, we have no note of anything ; I looked up that figure ; but I have no note of anything exceptional on that occasion.

24063. According to the analyses in Table V., the water of Bradford Beck is practically a sewage ?—It is.

24064. You would classify it as rather a bad sewage, would you not ?—It is. The whole of the sewage of Bradford after a very slight settlement, precipitation of solids by sulphuric acid, is thrown into the Bradford Beck about half a mile above this point where the sample was taken.

24065. Then as regards the analyses in Table XII. of water of Dewsbury Beck at junction with Calder, I should like to repeat the remark that I made with regard to the river Aire analyses (Question 24060). There is a case on the 5th of September, 1902, when the water at Dewsbury Beck had solids in suspension and solution amounting to 363, and in all the rest of the figures in that line are corresponding enormous increases over the other figures. Are there dams at Dewsbury Beck ?—There are a very large number of sluices across the stream, and I intended to put before you some evidence as to the raising of those sluices and the effect that it has on the stream. It is the practice to raise the sluices almost always on Saturday at mid-day, and the flow of the stream goes up from an average of 1,800,000 gallons to as much as 24,000,000 at mid-day. I have brought samples—I have them in the other room if the Commission cares to see them—of the stuff that is sent down at such times.

24066. That is very much like letting out a dam ?—It is the same, but it is a very much fouler stuff in the Batley Beck than in almost any dam.

24067. The results of the analyses of the water of Hebble Brook, Table XIII. ?—May I say that I have here an analysis of the flow in the Batley Beck on Saturdays when the sluices are taken up, and the total solids amounted to 617, solids in suspension 451, and oxygen absorbed 52.

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24068. That is a very bad sewage ?—Very bad.

24069. Then Table XII., Dewsbury Beck, and Table XIII., Hebble Brook, and Table XIV., Spen Beck at junction with the Calder—they are all extremely bad, too ?—Yes. These are smaller manufacturing streams. The Hebble Brook carries with it all the sewage of Halifax passed through septic tanks only.

24070. Then follow a number of very good rivers—Tables XV., XVI., XVII., XVIII., and XIX. Have you no contact beds at Halifax ?—They are not carried out yet. We have served them with a notice of proceedings, and they say that this summer they are going to put down their contact beds ; they have only septic tanks so far. Table XVI is not a good one ; that is the river down below Sheffield. If you compare that with the Don at Wortley, you have in the one case the albuminoid ammonia at ·009, while in the other at .043. The curious thing about the Don, if I may mention it, is that the nuisance arising from the River Don below Sheffield is probably the worst nuisance we have on any of our streams, although, as you see, the state of the stream is not nearly so bad as the others. I attribute it myself to the fact that the sewage of Sheffield is precipitated by lime and then discharged into the River Don, which is full of ochre water which causes a deposit, and the sludge deposit putrefies and gives off a very large amount of sulphuretted hydrogen. There, too, of course, they have a scheme before the Local Government Board.

24071. We were hearing about it yesterday. Has any bacteriological examination been made of the sludges to which Table XXIII. relates—the sludges from mill dams ?—No.

24072. None ?—No.

24073. The only other remark I have to make is that in Table XXIII. the stream of the Don at Sheffield shows a very large amount of nitrogen, 3·104 ; that is a remarkably highly nitrogenous effluent ?—That is coming from the mill dam while sludging is going on.

24074. That involves a quantity of organic matter ?—Yes ; all that may be deposited in the mill dam.

24075. (*Colonel Harding.*) What is the object of one of the Tables—I think it is Table XXI. What do you propose to show us by that ? I notice, in connection with certain of these analyses there is an enormous amount of suspended matter. For instance, under head A Table XXI., there is a total of 658 of solids in suspension, which tails off gradually to 21. What is the object of the Table ?—I put it in—I am glad you mentioned it—to show the worst that we can get from a natural flood, and to compare that with what comes from the mill dams when sludging is going on.

24076. This Table really shows us what takes place in the river, at times of rain, quite independent of any pollution ?—Yes.

24077. From sewage or from trade refuse ?—Yes. These first four taken from the River Calder, A, B, C and D, were taken after a long drought, when a very sharp flood came on, as you will see from the rainfall. They probably represent the worst state of matters in the River Calder from natural causes—the washing down of silt in the river.

24078. I see, under heading D, that the river, while still falling, gave 21 parts of solids in suspension. What do you suppose would be the normal condition in dry weather ?—If you look at Table IX. you will find the normal condition there stated.

24079. What is it ?—Solids in suspension, 3·8.

24080. It is exceedingly interesting to find that owing to perfectly natural causes the stream at times has an enormously increased amount of suspended matter in it, represented by the figures 658 as compared with 3·8 ?—That suspended matter does not come from natural causes, but from the gross pollutions that are poured into the river higher up, and where solid matters are allowed to settle behind weirs.

24081. I am very anxious not to misunderstand what you say. These experiments are on the River Calder, which is an exceedingly foul stream ?—Yes.

24082. So that really these are not the natural conditions of the stream. The matters which are washed out at times of flood are grossly polluted matters which have been deposited in it ?—Yes. The one below represents more what takes place in a natural stream—the River Don—I put in the first four from the River Calder to show practically the worst that we can get from a storm without any dam sludging, and from the River Don to show what would result from a fairly natural stream.

24083. There the increase was comparatively slight ?—Yes. But it is still high.

24084. It would be rather interesting if the same data could be obtained from an unpolluted stream ?—Yes, I will endeavour to supply that.

24085. Are you able, in connection with the table referring to Hebble Brook, to point to any improvement within recent years as shown by analyses ?—I truly confess that I am disappointed that the analyses do not show the improvement one would expect. There is an improvement, but the analyses to show it definitely would evidently have to be taken very much more frequently than once a quarter. The result of the analyses depends so very much upon conditions of weather and conditions of separate discharges. Once or twice I have had the samples quite spoilt by the fact that one mill, close to the point where the samples were being taken, happened at that time to be discharging a very polluting effluent. Such things as that so greatly affect the analyses that I am not able to draw many conclusions from them, I am sorry to say.

Mr. Oscar J. Kirby, Borough Engineer of Batley, called ; and Examined.

Mr. Oscar J. Kirby.

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24086. (*Chairman.*) Could you tell me, very briefly, what is the system of sewage treatment at Batley ?—We treat it by hydrolisis and oxidation. It is hydrolised in a septic tank and it passes from the septic tank into the bacteria beds and is oxidised in the ordinary way.

24087. You hand in this statement ?—Yes.

Statement by Mr. Oscar J. Kirby.

I am the Borough Engineer of Batley. The population of this borough is 31,000. The area is 2,039 acres. Batley is the centre of the heavy woollen district, and is bounded on the north by the Borough of Morley ; on the south by the Borough of Dewsbury ; and on the east and west by the Urban Districts of Soothill, Upper Heckmondwike and Birstall respectively.

The separate system of sewerage has been adopted, *i.e.*, one set of sewers for sewage and another for storm water.

The levels of the ground surface vary from 140 feet to 485 feet above sea level, which gives rise to eleven natural streams.

The boundaries of the borough are chiefly water-courses.

In two instances hills have been tunnelled through to bring sewage to the main outfall works.

To bring all the sewage of the borough to one outfall would be a very costly undertaking, owing to the number of tunnels required.

The sewage from that portion of the borough which drains into the Heckmondwike watershed (61½ acres) is dealt with by the Heckmondwike District Council at their sewage outfall works.

The Howden Clough district (6½ acres), the Howley Beck district (256½ acres), and the Lamplands district (53 acres), are residential districts, the sewage from which could not be taken to the main outfall works without a good deal of expensive tunnelling.

Each of these districts is provided with a separate purification works, viz., with septic tanks and oxidising filter beds.

The sewage is all domestic and there has not been any complaints of smell or any other nuisance.

The main outfall works are being constructed, and when finished will consist of one covered detritus tank whose capacity is 94,000 gallons.

A pump well of 9,000 gallons capacity.

A covered septic tank which, when full, holds 1,750,000 gallons.

Ten single contact beds, having a total capacity of two acres a yard deep.

Ten double contact beds of the same capacity.

Four storm water beds of 3,500 cubic yards total capacity.

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The dry weather flow to these works is 500,000 gallons a day of twenty-four hours, viz., 300,000 gallons of domestic sewage and 200,000 gallons of trade wastes from woollen mills, blanket mills, dyehouses, carbonizing works, wool scouring, etc.

The main outfall purification works, also three small purification works and the surface water drainage scheme were all designed by me, and constructed by administration under my supervision.

The main outfall works are in a narrow valley, the slopes of both hills being built upon.

When the septic effluent is discharged upon the first contact beds the sulphuretted hydrogen gas in solution in this effluent is forced out of solution and escapes into the air, giving rise to a nuisance which is the cause of many complaints from the residents in the district and from persons who pass the works along the main road upon which they abut.

Even when the septic effluent is quiescent, any lowering of the barometric pressure will cause a corresponding lowering of the co-efficient of solution and the consequent escape of gas.

The following mechanical means were adopted to prevent the escape into the air of the sulphur gas, viz., the septic effluent is distributed into the contact beds upwards from a 12-inch cast iron pipe instead of being delivered into roughs or grips on the upper surface of the beds.

The covered channel conveying the liquid from the septic tank to the beds is connected by a 12-inch air shaft to the boiler house chimney (170 feet high).

Bafflers are fixed in this channel which disturb the liquid and force a portion of the gas out of solution.

This gas is drawn up the chimney and dissipated at the top.

It was my intention to fix a fan at the bottom of the chimney but the induced draught of the chimney has so far answered the purpose.

These arrangements have effectually removed any cause for complaints. But in order to be in an assured position to deal with the nuisance in the event of their failure, experiments have been conducted with a view to destroy the sulphuretted hydrogen gas.

Samples of bleaching powder were analysed (as bleaching powder varies in composition) with the object of determining the amount of soda which would be required to precipitate the whole of the lime in it, leaving a solution of sodium hypochlorite, which will destroy the gas, and is itself reduced merely to a solution of common salt.

The liquid from the septic tank was examined as it entered the beds, and as it finally left the works; the difference in the amount of gas in the two liquids was thus determined, the difference being the amount of gas which had escaped into the atmosphere and caused the nuisance complained of.

Solutions of hypochlorite of known strength were made and added to the septic effluent as it passed along the covered channel from the tank to the beds.

This was done on the worst days, i.e., when the smells were strongest, and repeated on other days.

It was found, however, that the solution would only need to be added on certain days, viz., on those days on which the bad smells arose, and with ordinary care it did not produce any solids in suspension.

To destroy the amount of gas on one of the worst days it required 7·25 grains of bleaching powder and 15·12 grains of soda crystals per gallon of septicised liquid, i.e., 9½ cwt. of bleaching powder and 19½ cwt. of soda crystals per 100,000,000 gallons of septic effluent at a cost of £5 11s. 6d.

Against this there would be a residual of chalk about 75 per cent. by weight of the bleaching powder used.

The maturing process in a new contact bed proceeded faster by the application of liquid in which the sulphur gas had been destroyed by these means than when the liquid applied is charged with the gas.

The following experiments were conducted with a view of preparing hypochlorite (or oxychloride) of soda by the electrolysis of salt water or brine.

The electrolytic cell consisted of a glass box 12 inches long by 18 inches deep.

The electric current was supplied from a 350 kilowatt dynamo through a motor generator.

In the first experiment, copper electrodes were used; these, however, were rapidly attacked on the current being passed, and copper salts formed.

In the second experiment the electrodes used were four round carbon rods, 11 inches in length and 1¼ inch in diameter; and the electrolyte a 5 per cent. solution of brine.

The available chlorine was only 2 per cent. of the total chlorine.

A third series of experiments were conducted with carbon plates.

Five such plates, each 5½ inches by 1¾ inches, were placed together, being separated at the terminal end by a strip of india rubber; and at the other end by short lengths of glass tubing, the whole being kept in position by rubber bands.

The centre and two end carbons were connected together to form the anode and the remaining two to form the kathode.

The 7½ per cent. solution of sodium chloride was first used, and a current of 14 ampères at 5 volts passed for one hour; by this means 7·36 per cent. of the total chlorine was converted into available chlorine.

A 3 per cent. solution of common salt (about the same percentage as sea water) was next used, and the same current passed for a period of two hours, the result being that 16·1 per cent. of the total chlorine was converted into chlorine available for the purification and deodorisation purposes.

This, at first sight, would appear to show a great saving compared with the case of the 7½ per cent. solution, but when it comes to a question of cost, this advantage is not nearly so great.

The chief cost is for the supply of electrical energy; the cost of such small quantities of salt (agricultural salt being used) employed for these experiments being negligible.

It would appear that in the second case the cost was practically double that of the first, and as the yield was only two and three quarter times as great as that of the first, the increase is only 37½ per cent.; and this advantage is doubtless due to the fact that in the first instance the solution became warm, thereby increasing the resistance offered by the solution to the electric current and also retarding the formation of sodium hypochlorite, as at high temperatures sodium chlorate and not hypochlorite is formed.

Further experiments were made to determine the effect of length of time of passing the current, sizes of the electrodes, also the time taken to obtain the maximum decomposition of the solution.

It was found, by using a 3 per cent. solution and a current of 9 ampères at 5 volts, that at the end of two hours the available chlorine was 14·4 per cent. of the total chlorine, and at the end of four hours it had fallen to 10·4 per cent., and after six hours was only about 3 per cent., this again being due to the increase in temperature of the solution, which rose from 10 degrees C. to 49 degrees C. during that time.

The surface areas of the electrodes gave the best results when the current was 0·33 ampère per square inch of pole.

A trial was also made, using a mercury kathode and carbon anode, but as the voltage required is much higher than for carbon electrodes, it is not an economical method of working.

To deodorise 1,000 gallons of the septic tank effluent, 5 gallons of the prepared liquid are required.

To prepare this liquid the total cost would be £6 15s. 0d. per 1,000,000 gallons of sewage treated, made up as follows:

3 per cent. of solution of common salt, 5,000 gallons required, *i.e.*, 1,500 lbs. of common salt, at 9d. per cwt.

	£	s.	d.
	1	10	0
Cost of current, assuming the installation of a machine giving 80 per cent. efficiency, and current at 1d. per unit - - - - -	6	5	0
	£6	15	0

Still further experiments have been made with a view to reduce the cost of producing oxychloride.

Endolithic carbon electrodes with terminals made to pass through them and secured to the sides of the electrodes with washers and wing nuts have been used.

Also electrodes whose terminals have been kept entirely outside the electrolytic cell, and consequently not subject to the action of the electrolite.

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It may be confidently stated with that a good electrolyser, working under favourable conditions, sufficient liquid to deodorise 1,000,000 gallons of septicised sewage can be prepared at a total cost of £3.

At a total cost of, say, £5 sufficient liquid could be prepared to sterilise 1,000,000 gallons of filtrate or final effluent.

The liquid can be prepared by the electrolysis of brine at a less cost than from bleaching powder; there is also a sensible difference between a solution produced from bleaching powder and one of the same strength produced by the electrolysis of salt water, viz: the latter will deodorise a greater quantity of either sewage or sludge.

24088. (*Sir William Ramsay.*) Might I ask you what are carbonizing works?—To get the wool from rags, to separate the wool from the cotton—I am now speaking of a mixture of cotton and wool—they are passed through a chamber in which there is an acid; the acid eats away the cotton and leaves the wool.

24089. Then what becomes of the acid. Does that run into the stream?—It runs into the works where they may try to use it again. It is a question that I could scarcely answer straight away, because in some cases they may use the spent acid for another purpose.

24090. It has a very dark colour, I presume?—Oh, it has.

24091. And it is fairly concentrated?—It is, certainly. I may say that the acid is often used to "crack the fat," as it is termed.

24092. That same acid?—Yes, the same acid.

24093. I supposed that might be so. I see that your filter capacity is one yard per 25 gallons. That capacity of filter should give very good results, should it not?—Yes. The present results are 98 per cent. of purification.

24094. That is very good?—The beds are comparatively new; they were opened only last year. I have a table here shewing the percentage of purification; at the present moment it is 98 per cent.

24095. That is very good indeed?—May I leave this table?

24096. Yes; it would be a very good addition to your evidence?—Then I will put it in. (*Table handed in.*)

The following Tables show (I.) the average results obtained at different stages in the process of purification; also a comparison of average analyses of crude sewage and of the Batley Beck; and (II.) a summary of purification results:

I.—Average Results obtained at Different Stages in the Process of Purification.

Sample.	Parts per 100,000.									
	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 3 minutes.	Oxygen absorbed in 4 hours.	Solids in suspension.	Solids in solution.	Total Solids.	Nitrites.	Nitrates.	Chlorides.
Crude Sewage (Main Outfall Sewer).	6·24	1·68	3·21	10·82	35·70	120·50	156·20	absent	absent	12·74
Septic Tank Effluent -	5·26	0·59	3·20	8·65	12·00	81·00	93·00	absent	absent	12·63
No. 1 High-Level Bed (First Contact).	5·20	0·64	0·718	2·47	4·04	105·44	109·48	absent	0·12	12·77
No. 1 Low-Level Bed (Second Contact).	4·00	0·32	0·32	1·36	2·31	115·17	117·48	trace	0·51	13·21

Comparison of Average Analyses of Crude Sewage and of the Batley Beck.

Crude Sewage (Main Outfall Sewer).	6·24	1·68	3·21	10·82	35·70	120·50	156·20	absent	absent	12·74
Batley Beck (as it flows past the Outfall Works).	2.03	2·91	36·85	61·14	405·00	199·00	604·00	absent	absent	15·67

II.—Summary of Purification Results.

Bacteria Beds.	Conditions of Working.	Period of Working.	Mean Purification per cent.			
			First Contact Effluent compared with Sewage.	First Contact Effluent compared with Septic tank.	Second Contact Effluent compared with Sewage.	Second Contact Effluent compared with Septic tank.
No. 1	Two hours double contact, 3 cycles per 24 hours.	8 Aug. to 1 Sept., 1904 -	68·1	54·5	78·3	68·4
No. 1	Two hours double contact, 2 cycles per 24 hours.	1 to 19 Sept., 1904 -	72·6	58·4	80·3	72·2
No. 1	Four hours double contact, 2 cycles per 24 hours.	20 Sept. to 8 Oct., 1904	75·6	64·1	81·9	73·5
No. 1	Twenty-four hours double contact, 3 cycles per week.	8 Oct. to 28 Oct., 1904 -	69·0	57·3	86·4	80·4
No. 2	Two hours double contact, 2 cycles per 24 hours.	31 Aug. to 20 Sept., 1904	65·0	51·3	69·7	58·0
No. 2	Four hours double contact, 2 cycles per 24 hours.	20 Sept. to 28 Oct., 1904	65·3	49·9	72·7	62·0

24097. When you discharge the septic effluent on the first contact bed you speak of getting sulphuretted hydrogen. Is it not possible so to discharge it that it is not exposed to air to any great extent ?—If it is discharged in troughs or grips it is in the open air at once.

24098. But could it not be managed so as to avoid bringing the liquor into the open air ?—I am doing so at present, I am discharging it into the body of the bed—at the bottom of the bed and filling the bed upwards.

24099. There is a very interesting point which you bring forward here, the oxidation of the sulphuretted hydrogen in the septic tank liquor by practically a bleaching powder, and the attempt to make hypochlorite electrically ?—Yes, and I think the latter is the cheaper method.

24100. Have you tried lime as a means of precipitating the sulphate of iron ?—Yes, I have.

24101. Is that way more expensive or not so satisfactory ?—It is not so satisfactory.

24102. It stops up the beds, probably ?—Yes, it does ; it forms a coating on the media.

24103. Do you find that there is any danger done to the bacteriological action of the beds by this hypochlorite ?—Not at all ; if it is only used in such quantities as to deodorise the sulphuretted hydrogen: it helps to mature a new bed.

24104. Does it not require very careful working to make sure that you do not have any excess ?—If it is delivered into the carrier from the septic tanks along a sparge pipe the pipe can be so arranged that you cannot put more in than is required.

24105. You could overdose it, no doubt ?—It could be done, but then you would sterilise your beds.

24106. Is not that a risk—does it not require very careful supervision ?—Ordinary supervision.

24107. Ordinary supervision does quite well ?—Yes.

24108. Do you judge by the smell whether the sulphuretted hydrogen has been removed ?—Yes.

24109. Do you use no chemicals ?—Only for my own information ; but it is quite possible and quite easy to tell by the smell.

24110. By the smell alone ?—Yes.

24111. Is there any reason for destroying the sulphuretted hydrogen except to avoid its becoming a nuisance ?—No, not at all.

24112. Because the cost is £5 11s. 6d. per 1,000,000 gallons of septic effluents. Is not that rather prohibitive ?—It could be done more cheaply.

24113. There is chalk afterwards to be recovered but that would not amount to very much, would it ?—You are speaking now of the hypochlorite.

24114. Yes.—With bleaching powder and soda crystals it is more expensive.

24115. You could not reckon on getting any large price for the chalk purchased ?—Not at all.

24116. You have tried the electrical plan ?—Yes.

24117. Did you use the town electricity for the purpose, or did you generate your own ?—I used the town electricity.

24118. What do they charge you per unit ?—A penny.

24119. That was only done during the day, I suppose ? That is all. It has to be taken off when their peak load is on.

24120. It still occurs to me that £5 per million gallons is a pretty heavy sum to pay ?—I have made further experiments, and find it could be done for £3.

24121. And do you find no disadvantage in turning a sterilised septic effluent on to the filter beds. Do they work just as well ?—Not if it is sterilised ; it is merely deodorised.

24122. You do not think the hypochlorite sterilises it, it merely deodorises it ?—If you dose it sufficiently you would sterilise it.

24123. But you maintain that it has not been sterilised ?—Yes.

24124. It attacks the sulphuretted hydrogen before the bacteria ?—Yes.

24125. Then as regards the general question : would it not be better to avoid the use of septic tanks and simply settle or use chemical precipitation, and then treat the sewage liquid on your filter ?—With the present composition of our sewage I think we are treating it as economically as we can—that is, by using the septic tank.

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24126. You mean that the septic tank is the most economical method?—Yes, at the present moment, with the composition of the sewage as it is at present.

24127. Is that including the cost of the deodorising? —Oh, yes.

24128. Including everything?—Yes, certainly.

24129. Including the £3 per million gallons for deodorising?—Yes.

24130. I should have thought the danger would be of over-stepping the mark, and using too much hypochlorite and sterilising your filters; but you do not appear to find that to be the case?—With ordinary care it need not be done.

24131. (*Major-General Carey.*) You say the separate system of sewerage has been adopted, viz., that of one set of sewers for sewage and another set for storm water. Does the storm sewage receive any treatment before going into the river?—Yes, on storm water beds.

24132. You do not mention it here?—We have a separate system, and I leap the water into the ordinary clear water sewers; *i.e.*, say a storm comes on for a very short time, that goes into the foul water sewer, but when the storm becomes sufficiently strong it leaps into the clear water sewer or surface water drains.

24133. Does it receive any treatment after that?—Oh yes, the ordinary treatment.

24134. After it enters the clear water sewer?—Yes.

24135. Treatment on filter beds?—Treatment on storm water filter beds.

24136. At what period of the storm would these storm sewers come into operation?—When the storm is heavy. The first washings would go into the sewers, and as the storm increases the weirs would leap, and it would all go forward on to the storm water beds.

24137. I understand that; but how are the weirs regulated; at what period would they come into operation?—I leave about two inches more or less (according to the gradient) in a 12-inch clear water sewer, so that the first washings only go into the sewer; but when the storm is subsiding again the foul water goes into the sewer.

24138. And what number of dilutions would that represent?—About six.

24139. The volume that goes forward, and the volume that is intercepted?—The volume that goes forward would be six, and what is intercepted is often worse than what is in the sewer. I mean that householders put domestic filth down the ordinary street grates, and that passes into the sewer, and does not come on to these beds.

24140. At one period of the storm you pass the storm sewage into the ordinary fresh water sewer?—Yes, as soon as the weirs leap.

24141. And then it goes on to the storm beds?—Exactly.

24142. And is that sufficient to purify the dilute sewage?—The beds will purify it.

24143. Have any analyses been made of the effluent from the bed?—I have not made any. In fact the beds are not finished. They are not in a state at which I could make any analyses.

24144. If the nuisance caused by the septic tank effluent being delivered on to the contact beds were so great as to necessitate this treatment, it is rather costly treatment?—It is, yes. I may say that at the present moment the mechanical arrangements are sufficient. You notice in my statement that I say the mechanical arrangements at the present moment are sufficient. I have pipes. (The witness explained a plan to General Carey.)

24145. Is there any peculiarity in the sewage to account for the excessive nuisance of the septic tank effluent?—There is a lot of sulphur in the sewage, and I suppose that is the reason of there being so much sulphuretted hydrogen.

24146. Are there any tanneries or wool scouring works?—There are wool scouring works but no tanneries.

24147. (*Sir William Ramsay.*) About this electrical treatment. You put down the cost of deodorising the sewage at £3. and you go on to say "at a total cost of say £5 sufficient liquid could be prepared to sterilise a million gallons of filtrate or final effluent." If there was nothing to deodorise at all, would the cost of sterilising be £2—the difference between £5 and £3?—No, it would not; it would be £5.

24148. It would be £5?—Yes.

24149. (*Mr. Stafford.*) What do you do with your sludge?—I have not any.

24150. As yet?—I have had the tank going for two years, but there is no sludge yet.

24151. What do you propose to do with it; I suppose you will have sludge?—I shall deal with it when the time comes with hypochlorite of soda, which would deodorise it and there would be no nuisance.

24152. Why is there so much nuisance from this septic tank of yours?—The capacity of the septic tank is about 1,750,000 gallons, and I have an idea that the sewage is hyperhydrolysed, and that causes it to some extent.

24153. Causes the nuisance?—I think so, partly. But in addition, whatever size the septic tank might be, there would be a nuisance from the sulphuretted hydrogen; there would be some nuisance, if not as much as now.

24154. The septic tank is too big?—At the present moment; but I think the Committee wisely made it large enough, because we do not have at present what we shall have to deal with when treating additional sewage and trade waste.

24155. You think this gives rise to the nuisance?—To a great extent.

24156. (*Major-General Carey.*) What is your rate of flow through the septic tank?—26 hours.

24157. (*Mr. Stafford.*) Why do you not make it smaller for the time being; would not that stop the nuisance?—It would be an expense to do so. Of course the works are not quite finished; there is only a portion of the bacteria beds constructed. When dealing with the whole amount we shall be in a better position, and shall do better.

24158. Have the mechanical means which you have adopted to prevent the escape of air in any way impaired the efficiency of the contact bed?—Not at all; because it merely takes the sulphuretted hydrogen away, and my own impression is that the sulphuretted hydrogen masks the oxygen in the beds. If the septic effluent is overcharged with sulphuretted hydrogen it is better to extract it, or to destroy it, or change it.

24159. It has not impaired, in your experience, the efficiency of the bed in any way?—Do you mean drawing off the sulphuretted hydrogen.

24160. Yes?—Not at all.

24161. (*Colonel Harding.*) You have certain outlying districts in which you have separate little sewage installations, the treatment being the same there as in the main outfall?—Yes.

24162. You have not said about there being any nuisance in connection with the septic tanks there? There is none.

24163. Then there is none in those septic tanks for the outlying districts, but there is a serious nuisance in the septic tank at the main works?—That is so.

24164. At the main works you have not merely domestic sewage, but you have trade effluents to the extent of two-fifths?—Yes, exactly.

24165. Are there no trade effluents in the outlying districts?—None whatever.

24166. To what extent do you attribute the nuisance produced at the central works to the admixture of these trade effluents?—I am afraid I can scarcely answer that question.

24167. You have told us that in the outlying districts with septic tanks you have sewage wholly domestic?—Yes

42168. And that there is no nuisance?—That is so.

24169. While at the main works, again, having septic tanks you have a serious nuisance?—Yes.

24170. One difference between the two is that at the central works you have, in addition to domestic sewage, a quantity of trade effluents represented by the figure of two-fifths of the total ?—Exactly.

24171. May not the presence of those trade effluents affect the question of the nuisance ?—I think that is it.

24172. You think the nuisance is due to the presence of trade effluents ?—Yes, to a great extent.

24173. What is their general character; is it wool washing water ?—There is cloth scouring and wool washing and dyeing.

24174. You are under the impression that the addition of these trade effluents has brought about the nuisance at the main works ?—To a great extent. I may say again that in my judgment the sewage at the present moment is hyperhydrolised; it is over-septicised.

24175. But that is another matter altogether, is it not ? It is.

42176. You have told us that you think it is due to the presence of trade effluents, and then you also tell us that it is due to the over-septicising of the sewage ?—To both.

24177. Do you mean it is due to both causes ?—To both causes, certainly.

24178. Which is the more important cause, do you suppose ?—Oh, the trade effluent.

24179. Are you quite sure of that. You told me that you over-septicised the sewage, in your belief. The capacity of your septic tank is over 1,000,000 gallons ? —1,750,000 gallons.

24180. The dry weather flow is only 500,000 gallons ?—That is so.

24181. Therefore the flow is not, as I understood you to answer just now, a 24-hour flow, but a 48-hour flow ? —In answering General Carey I was supposing that the works were purifying what we are supposed to—1,100,000 gallons, and not merely the dry weather flow.

24182. We are to take it that the works have been constructed to deal with a much larger volume than you are now dealing with ?—Exactly.

24183. At the present time the flow through your septic tank is a very slow flow ?—Very slow.

24184. Such as would fill the tank in 48 hours ?—Yes.

24185. And you yourself are under the impression that it stays there too long ?—I am.

24186. Would it not really be worth your while, in order to obtain the very important information whether reducing the capacity of the septic tank would not stop this nuisance; would it not be worth your while to try that ?—It would not stop it entirely, because in flood times I have an opportunity of putting the sewage through the sepic tank faster.

24187. But then the conditions are different, because the sewage is dilute ?—Yes, it is.

24188. Would the cost of dividing your septic tank be very great ?—Rather costly owing to its depth.

24189. I ask you because several witnesses have expressed to us the opinion that leaving the sewage too long in a septic tank does bring about a greater development of sulphuretted hydrogen ?—I am quite of the same opinion.

24190. Would it not be worth your while to spend some money in the experiment of reducing the capacity of your tank, say, by a cross wall provisionally in order to find out whether the production of sulphuretted hydrogen is due to the over septicising or to the other cause which you have mentioned ?—No doubt it would; but we are making all speed with the works so as to be able to treat the whole of the sewage.

24191. When do you expect that you will get your full flow ?—Some time this year or at the beginning of next.

24192. Your answer is that expecting so soon to have a normal rate of flow through the tank, you do not think it worth while to spend the money ?—That is so.

24193. That would be prevention rather than cure, would it not ?—Yes, it would.

24194. It is interesting any way to have an example of a case where a nuisance has been produced from the septic tank flow and where a serious attempt has been made to cope with the nuisance. We gather that you have been able to do that ?—Yes.

24195. The mere collection of your gases with a chimney stack you think has brought about the removal of the nuisance ?—Oh, it has.

24196. If that were not sufficient you were prepared to do something more, as you have shown us by your interesting experiments ?—Yes.

24197. In passing the effluent from your septic tank to your contact beds and delivering it at the bottom of the contact beds instead of as usual on the top, have you found that there is any reduction in the effectiveness of the contact bed filtration ?—Not up to the present. Around the end of the pipe there is certain small matter, but that has not got into the bed. We should have had that on the top of the bed if we had delivered it at the top.

24198. Did you take any analyses so as to give you any idea of the results obtained before and after this filtration ?—Yes.

24199. Did you find any material difference ?—Not any.

24200. You are of opinion that it does not matter whether one delivers the sewage on to a contact bed at the top or into it in the body ?—I should prefer to deliver it on the top.

24201. For what reason ?—I think it may take up more oxygen—in a thin spray, I mean.

24202. And probably you would have the chance of retaining on the surface some of the suspended matter ? —That is not a very strong point, because it collects itself around the end of the pipe. It is all in one place instead of being distributed all over the bed.

24203. If it is at the bottom, how can you prevent its going off with the filtrate ?—The beds empty in the middle, and this is delivered at one end.

24204. How can you get at the accumulations near the pipes so as to remove them without digging down ? —Not without digging down.

24205. You have to dig down ?—We have to dig down.

24206. Are you able to tell us what suspended matter goes on to your contact beds—roughly ?—About twenty grains per gallon.

24207. I do not wonder that your septic tank does not get full of accumulations if you carry away from it so large a proportion of the suspended matters. Are you quite sure of that figure ?—That is the total solids, not the suspended solids; the suspended solids are about four, at the present time.

24208. The suspended solids going on to your filter are not twenty, but four ?—About four—from four to six.

24209. What amount per gallon do you leave behind in the septic tank ?—I could not say.

24210. What is the amount of suspended matter in the average analysis of your sewage. It would be thirty of forty, would it not ?—About forty-five.

24211. And you only carry away in the effluent four ? —Yes.

24212. Therefore you must leave about forty in the tank ?—Yes, I suppose so.

24213. Are we right in understanding you to say that after two years you have no appreciable accumulation in the septic tank ?—We have not emptied any sludge from the septic tank yet.

24214. Have you considerable accumulations in the tank ?—I do not think so.

24215. Have you attempted to gauge whether there is any accumulation ?—Only with the rod.

24216. And you felt the bottom easily ?—Oh, easily; the rod will fall to the bottom.

24217. But that does not necessarily mean that there is not a great deal of thin sludge ?—No doubt there is.

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24218. Do you really seriously expect that the forty grains which you leave in the septic tank are going to be absorbed or changed by bacteriological or other action?—The tank is 13 feet 6 inches deep on the average, and it is rather difficult to tell what there may be at the bottom. No doubt we shall have to clean it out.

24219. You expect that?—Oh, I do, certainly.

24220. There will be accumulations?—Certainly.

24221. You expect that, but on account of the great depth of the tank it has not yet troubled you?—Just so.

24222. And you probably foresee that as the accumulations increase your effluent going on to the contact beds will contain more and more suspended matter?—Exactly, yes.

24223. And when it reaches such a point as to be seriously objectionable you will then empty the septic tank?—We shall then empty the septic tank, which can be done from the bottom without any difficulty.

24224. The Commission will be very much interested to know whether when you get your full rate of flow through the septic tank, and reduce what you have considered to be the over-septicising of the sewage there disappears at the same time the nuisance of the sulphuretted hydrogen?—Yes.

24225. You have not troubled yourself in the least about what you will do with the sludge as yet?—No; it has not troubled us.

24226. But you will in the course of a certain length of time—probably another year or two years—have to remove a good deal of sludge?—I certainly expect to.

24227. Can you suggest what will be done with it?—It will be deodorised and taken on to land.

24228. You do not foresee any difficulty in getting rid of it?—Not any.

24229. And you say that by the use of the septic tank you will have much less sludge to deal with than if you had settlement assisted by chemicals?—Certainly.

24230. That is indeed the reason why you selected septic tanks?—Yes.

24231. And you are quite satisfied with your selection?—Up to the present moment, yes.

24232. You have had nuisance, but you have remedied it?—Yes.

Mr. J. P. Wilkinson, Engineer at the Sewage Disposal Works of the Corporation of Manchester, called; and Examined.

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24233. (*Chairman.*) You are Mr. Wilkinson, engineer at the Sewage Disposal Works of the Corporation of Manchester?—Yes, I am a member of the Institution of Civil Engineers and of the Association of Municipal and County Engineers practising in Manchester. I have planned and carried out the new works at Davyhulme for the Bacterial treatment of the Manchester sewage.

24234 What is the population draining to the Manchester Works?—The population draining to the sewage works at Davyhulme is 575,500. This is inclusive of portions outside the city area which drain into the city sewers by agreement; but is exclusive of districts recently added to the city which have sewage works of their own elsewhere.

24235. What is the system of drainage?—The area is almost entirely drained upon the "combined" system; that is to say, the storm water is not to any great extent drained into a separate system, but is delivered into one system of sewers, from which the excess above a defined amount of dilution is overflowed into the streams. In comparison with the extent of the area drained, the amount of separate surface water drainage is very small indeed.

24236. Is there any infiltration of subsoil water into the sewers?—There is a considerable amount of infiltration of subsoil water into the sewers, and many of the older sewers of the city were constructed with a view to its admission to a certain extent. The average volume is probably about 6,000,000 gallons per day.

24237. What is the water supply per head, and from what source does it come?—The water supply of the city may be taken at an average of 29 gallons per head per day; of which 16 gallons is supplied for domestic and 13 gallons for trade purposes. It is derived partly from Longendale on the borders of Cheshire, Derbyshire, and Yorkshire; and partly from Thirlmere in the Lake district.

24238. Is it hard or soft water?—From both sources the water supplied is a soft water.

24239. What is the drainage area of the part of the city which is sewered?—The drainage area of the sewered portion of the city proper is about 10,000 acres, exclusive of undeveloped land; and the total area (inclusive of outside districts admitted under agreement to the sewers) is about 11,800 acres.

24240. What proportion of the population use pail closets or middens, and what proportion use water-closets?—About 62½ per cent. of the city population use pail closets and middens; and 37½ per cent. use water closets. This will apply to about 560,000 of the population draining to the works; for the remaining 15,500 there are not figures available.

24241. Has the flow of sewage to your works been gauged? If so, what is the average number of gallons delivered at the works per day of 24 hours in dry weather in winter and in summer?—The flow of sewage to the works has been gauged. The average flow per 24 hours in winter dry weather (October to March inclusive) is found to be 26,481,000 gallons; and in summer dry weather (April to September inclusive) 25,311,000 gallons.

24242. What is the maximum dry weather rate of flow, and at what hour does this occur?—The maximum dry weather rate of flow is 37,236,000 gallons per 24 hours, occurring at 2 p.m. at the sewage works, 4½ miles from the city.

24243. What is the minimum dry weather rate of flow?—The minimum dry weather rate of flow is 18,644,000 gallons per 24 hours, occurring at 6 a.m. at the works.

24244. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued?—The maximum wet weather rate of flow observed coming to the works is 222,625,000 gallons per 24 hours extending over a period of two hours.

24245. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation? For comparative purposes kindly give the maximum and minimum rates of flow in dry weather in the sewers on which the various overflows are situated?—There are in all about 215 storm water overflows on the sewerage system, which are designed to come into operation when the amount of sewage is diluted with five additional volumes of rain water. The number of overflows is so numerous, and the sizes and gradients of their sewers so varied, that it is not possible to give a reply in full detail to the latter part of the question; but typical instances which have been under observation showed the following results:—

	Maximum rate per 24 hours.	Minimum rate per 24 hours.
A. Temple Street -	29,800 gals.	11,250 gals.
B. Downing Street -	590,000 gals.	170,000 gals.
C. Union Street (Ardwick) - -	310,000 gals.	108,000 gals.
D. Deansgate - -	257,000 gals.	20,500 gals.

The above observations were made in dry weather, but at a time when the subsoil water might be supposed to be at its maximum rate.

24246. What is the largest number of gallons of sewage which have passed the last storm overflow and come to your works in 24 hours?—The largest number of gallons of sewage which have passed the last storm overflow, and come to the works in 24 hours was 163,624,000 gallons, occurring on Tuesday, August 7th, 1900.

24247. Can you say what is the volume of water in gallons represented by the average yearly rainfall in

the drainage area?—The average yearly rainfall on the drainage area is equivalent to 8,432,943,750 gallons.

24248. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year, and the volume which passes over your overflows?—The volume of sewage coming to the works during the year is approximately from 12,000 million to 13,000 million gallons. The amount passing away by storm overflows cannot be stated with any degree of accuracy.

24249. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather; and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source?—The infiltration of subsoil water into the sewers is no doubt continuous, varying to some extent with the seasons; *i.e.*, as between summer and winter; and also with the state of the weather, being greater in volume during and for a certain period after heavy rains. Probably the daily infiltration in winter is from one to two million gallons in excess of that in summer.

24250. How many gallons of trade effluent enter the sewers daily (24 hours), and what is the nature of these effluents?—The estimated volume of trade effluents entering the sewers daily is $3\frac{3}{4}$ million gallons. The trade effluents consist of waste liquor from sulphate of ammonia works, brewery refuse from breweries, mineral water manufactories, bottling works, etc., waste water from dyeing, bleaching, printing, mercerising, and furnishing works, tanneries, galvanising works, general chemical works, including aniline and tar distilling works, refuse from tripe dressing, bone, size, and candle works, railway companies' waste water from sponge cloth and carriage washing, etc.

24251. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—Portions of the internal sewerage of the city are of very ancient date, but the major part has been constructed and remodelled continuously with the growth of the city during the last half century. The interception system cutting off the sewage from the rivers dates from about 1888. No doubt some of the older sewers have settled in places, and have become sewers of deposit, but there is no reason to think that such instances are numerous.

24252. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possible the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—In my judgment the requirement of dilution by storm water up to a maximum represented by one volume of sewage to five volumes of rain is a reasonable one for purposes of special filtration, two volumes of the mixture being dealt with in the ordinary plant, and four volumes on storm-water filters. There is, however, a wide difference between the character of an average sample of sewage through the twenty-four hours, or one taken at the minimum and one taken at the time of maximum flow. If a minimum addition of five volumes of rain be the lowest requisite as a dilutent in order to render storm water harmless before passing it into the river, it seems reasonable that the standard measure of dilution should be applied at the time of the *maximum* flow, when the foulness is greatest. If the *average* rate of flow be taken as the controlling factor for dilution, the value of the five-volume provision, as a measure for the protection of the river from putrescible and suspended matter is largely neutralised whenever heavy rain occurs at the period of maximum flow. The Manchester main outfall sewer is capable of delivering sewage and rain at a rate equal to six times the maximum flow. As a general rule, under the latter circumstances, where the overflows are adjusted to the *average*, sewage will pass away to the river at the time of maximum flow diluted with *three* volumes of rain instead of *five*. If, in addition, the heavy rain occurs after prolonged drought, when deposits of accumulated filth are necessarily swept from the sewers, the amount of putrescible and suspended matter sent to the river may be very considerable. I am of opinion that in all local overflows the actual observed maximum and not the average rate of flow should be the determining factor for dilution. In the local overflows it does not seem to me to be possible to base the dilution upon the water supply per head of the population, which may be in manufacturing neighbourhoods more than double the amount in working-class localities. Where a considerable volume of sub-soil water enters the sewers this should be taken into account at the final overflow, which should be placed at a point as near as possible to the town, so as to avoid unnecessary size and cost in the outfall sewer. The amount of water supplied to the town at the time of minimum flow, with statistics of the amount used at that time from other sources, and careful gaugings of the sewer at that time, will enable the amount of sub-soil water to be determined with close approximation to accuracy. But in large towns, for the purposes of overflows, the volume of water supplied is generally speaking, owing to its variability through the day and in various localities, not a sufficent or reliable guide. Dilution up to six to one at the time of maximum flow involves, however, the disadvantage of having to take to the works a needlessly high volume if heavy rain occurs when the sewer is flowing at the minimum or at the normal rate. The five volumes of rain added at *maximum* rate of flow is equivalent to eight volumes at time of average flow, and 11 volumes on the minimum flow, at the time when the putrescibility of the sewage, as measured by the oxygen absorption figure, is only one-half of that at the maximum. For comparative purposes and from the point of view of putrescibility, therefore, the application of the standard dilution of six to one at the time of maximum flow is equivalent to a dilution of 24 to 1 at the time of minimum flow. Clearly, this is a practical anomaly which ought to be removed; though in a gravitation scheme it may be a matter of some difficulty. In a pumping scheme it is readily met, as the volume pumped can easily be adjusted to the requisite dilution of either the maximum, average, or minimum quantity. The best alternative in a gravitation scheme would be the provision of duplicate or multiple inlets to the works proper, in connection with a regulating chamber, one or more of which inlets could be shut down to suit circumstances, thereby delivering a certain volume to special tanks and thence, after settlement, to the river direct. Probably such a limitation could very well be made in the case of most sewage works during eight hours out of the twenty four, and valuable relief afforded to the ordinary plant and storm filters at a time when it is most needed, during the night or early morning, without any injury to the rivers. In any case it is evident to me that a wide discretion ought to be left with the authorities at the works in dealing with these variations in the flow. I have stated elsewhere my opinion that the volume passed through septic tanks in time of storm should be limited to a dilution of one volume of sewage by an equal volume of rain. (See reply to 24272.) I do not think that settlement alone would be sufficient for the whole of the sewage arriving at the works in times of storm, though I think it would be sufficient for all that might come during the period of eight hours at the minimum flow, which I have referred to, after one additional volume had been taken into the ordinary plant. Special tanks should be provided for this purpose, with direct outlet to the river and connected to the regulating chamber referred to above. In brief, therefore, my suggestions for the treatment of rainfall would be as follows:—

(1) - -	At all times	Two volumes mixture of rain and sewage through septic tanks and ordinary plant.

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(2) - - For sixteen hours out of twenty-four	{	Do. do., and up to four additional volumes through storm water filters.
(3) - - For the remaining 8 hours.	{	Two volumes sewage and rain through ordinary plant, and remainder by settlement in special tanks.

So far as my judgment as an engineer is of any value I do not think that in the last case (3), any addition of chemicals would be necessary.

24253. What shape and size are your storm overflows?—The storm-water overflows on the Manchester system of sewers vary in shape, size, and arrangement according to the special circumstances of each case. They are very numerous.

24254. Would it be possible to have a standard form of overflow, and how would you fix the point at which overflows should be allowed to come into operation?—I do not think it would be possible to have an absolute standard form of overflow. Generally speaking, in a properly-constructed overflow, suited to a sewer draining a completely developed area from which the sewage has reached its probable maximum, the determining factor is the difference in level between the invert of the tributary sewer at the overflow, and the invert of the communicating pipe at its entry into the intercepting sewer. This difference in level would ordinarily fix the gradient of the communicating pipe, and therefore its diameter or dimensions for the conveyance of the defined quantity; and it must be fixed at its upper end even with the invert of the tributary sewer. The gradient and dimensions must be such as to convey the defined quantity when running full. The sill of the overflow should be of such a length as would admit of discharging the difference between the defined amount and the full discharging capacity of the tributary sewer, without unduly increasing the head upon the communicating pipe. Perhaps one-fourth the diameter of the latter is the extreme limit to which the water level when flowing on the sill should rise above the soffit of the communicating pipe. If the disparity between the tributary sewer and the communicating pipe is too great to admit of this being done in one chamber a second chamber at a higher point should be provided to reduce the volume to the necessary limit. Where the tributary sewer drains a partially developed area on which the volume of sewage has not attained its maximum, the communicating pipe should be put in of the proper size and gradient for the ultimate quantity, and its inlet closed by an orifice of less dimensions, which may be adjustable. I regard these as the essential features of a properly constructed and complete overflow, which must be complied with if the ultimate central authority is to be satisfied that its requirements as to dilution are complied with, and at the same time the subordinate authority is to be sure that the sewer is not receiving more than the proper amount. Local overflows in the town should, as a rule, dilute the sewage flow with five volumes of rain when it is at its *maximum* rate of flow, and this should be exceeded rather than otherwise, so far as is consistent with the safety of the intercepting sewer. The difference should be adjusted at a main overflow below the point of connection of the last tributary sewer from the town, so as to obviate needless cost in the main outfall. In some cases of sparsely populated area where the overflow necessarily requires frequent readjustment, the leaping weir seems to afford a valuable type of overflow, which, though not admitting of great accuracy in adjustment, is sufficiently so to give an approximation to the correct quantity; care being taken to err on the side of excess, and provide for rectification at the main overflow, as mentioned above.

24255 Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically?—With regard to the point of dilution at which storm water overflows should come into operation, I have no doubt that it is possible to discriminate to some extent between sewers having rapid and self-cleansing gradients and those which, owing to the configuration of the land, are of necessity flatter, with a velocity which does not reach the self-cleansing point until the sewer is half or more than half full, if at all. In sewers of the former type any deposit is rapidly removed with a comparatively small flow, while in the latter cases a sluggish flow may require a considerable period at the maximum velocity of which the sewer is capable. Flushing operations may in some cases necessitate the temporary raising of the overflow sill, so as to ensure that foul water shall not be carried into the river. Any variation from the general rule of dilution should only be made after careful observation of each case, and much will depend upon the amount of attention given to the maintenance of the sewers in a clean condition. I do not think that the geological character of the surface soil is a very important element in the question. A more important factor consists in the circumstances of the district drained by the sewers; for example, whether mainly covered with impervious paving or with macadamised or gravelled roads permitting of rapid discharge, or on the other hand of a large amount of percolation. Experience at Manchester seems to indicate that each storm overflow should be the subject of careful supervision, and that the volume to be admitted to the intercepting sewer should be carefully settled in each individual case. Wherever it is desirable for any reason to have movable overflows any alteration should only be made under proper authority.

24256. Should storm overflows be fixed or movable?—As a general rule overflows should be fixed, except where the tributary sewer drains undeveloped land on which population is increasing. In such cases they should be capable of adjustment to meet changed conditions. In these cases also it is advisable that the overflow sill should be fixed and the adjustment made in the size of the orifice admitting the defined quantity to the intercepting sewer. The last overflow on leaving the town at the upper end of the main outfall sewer should be absolutely a fixed one. These remarks refer to overflows on the sewers proper, and not to any regulating chamber at the works as suggested under 24252, for the separation of the night storm flow for diversion into special settlement tanks.

24257. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case?—I think that the number of dilutions at which storm sewage may properly be allowed to pass into the stream may be to some extent made dependent upon the size and nature of the stream into which such sewage would pass. But the limits within which the number of dilutions may vary are, I think, in practice small. I am disposed to regard dilution by five volumes of rain at the time of maximum flow as the highest practicable economic limit for purification by most authorities, and at the same time the lowest consistent with the protection of the stream from putrescible and suspended matters. The latter is, I think, especially the case having regard to clearance of sewers after rain:—

(1) In more or less level, low-lying districts, with sewers having flat gradients.
(2) In thickly built up urban areas.
(3) After long periods of drought.

In the case of Manchester I regard each of these proportions as approximately true. It follows, therefore, that only under very special circumstances connected with the size and nature of the stream can these limits be materially varied. Such circumstances I should consider to be:—

(1) Extreme disparity in volume, where the stream is small in proportion to the storm flow.
(2) Deficient velocity in the stream, and its inability to carry forward suspended matters.
(3) Delicate or imperfect regimen of the stream, where the velocity necessary for discharge of the water tends to become too great for the tenacity of the soil over which it flows.
(4) Sinuosity of channel at or below the point where storm sewage would enter.
(5) Use of the water for domestic purposes below the entry of the storm sewers.
(6) Preservation of the stream for fishery purposes.

As to (1).—Such cases may, and often do, arise where the sewage is treated in the catchment area of a stream subordinate to the main river on which the town where the bulk of the storm sewage arises is situated. In such instances it will be found advantageous to deliver as much of the storm sewage locally as is possible, and if the stream is one which easily carries forward suspended matters and the separate system is applied as

far as possible, a diminution in the number of dilutions would be a practical possibility and an economic advantage.

As to (2).—Where these conditions exist it would seem that an increased volume consistent with the power of the stream to adapt itself to it without danger of flooding, etc., would be an advantage. But the storm sewage thus admitted should itself carry an amount of suspended matters well within the powers of the stream, and under such circumstances its admission in increased quantity would be helpful.

As to (3).—Wherever a stream flows through lands of a gravelly or sandy nature, it is quite likely that the regimen is so delicate that the velocity cannot be increased without great danger of increased erosion and consequent possible damage to adjoining lands in such cases. If the storm sewage be admitted at one point, care must be taken to approximate its velocity at the point of confluence to that of the stream. In this event the impounding of storm waters to be delivered after settlement, and at a gradual rate after rain has subsided, may be more important than an increase in the number of dilutions at which the storm sewage is allowed to enter the stream.

As to (4).—It often happens that towns are built upon a stretch of river which pursues a very tortuous course through the built up area; on a site near the entrance to an estuary or low-lying land at the confluence with some other stream. It is also often the case that the sinuosity of the channel, accompanied by a reduced gradient, and confinement perhaps between banks lined with buildings limiting its discharging capacities, renders it only capable of delivering with difficulty the upland waters, and inadequate for receiving safely a large volume of water from the streets and buildings through which is passes. In such cases the number of dilutions at which storm sewage should be allowed to enter the stream may be increased almost indefinitely and to an extent amounting to absolute interception of storm sewage from the stream within the town limits, and its delivery at a suitable point lower down the river, where it can be delivered free from danger.

As to (5).—Where the water of the stream is used for domestic purposes the six to one limit of dilution should be enforced, and even increased with adequate filtration and settlement of all storm sewage before admission to the river.

As to (6).—Where streams are under preservation for fishery purposes the removal of both putrescent and suspended matter is also important, and, as a general rule, I think the six to one limit for dilution ought to be maintained.

24258. The city is not drained on the separate system, and you can therefore give no analyses of the road water separately?—No.

24259. Do you consider that in certain circumstances the road water should be purified?—I think that even if the "separate" system is installed the early flush of road water should be admitted to the sewers proper, and be purified with the sewage. Either the "leaping weir," as described in 24254, or storm water overflows of a special type may be employed for the purpose of separating a defined quantity.

24260. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers?—I cannot say that, in my judgment, for the majority of urban areas at any rate, the "separate system" possesses any very material advantages as compared with the combined system of sewerage. The several conditions under which the alternatives may have to be considered seem to group themselves under four heads, viz.:—

(*a*) Old towns and "built up" urban areas generally.
(*b*) Residential districts and rural areas.
(*c*) Cases where the whole of the sewage is pumped for treatment.
(*d*) Tidal outfalls.

In the case (*a*), embracing old towns and built up urban areas generally, I think the "combined" system possesses preponderating advantages. It is usually considered impracticable to carry out a duplicate or separate system of sewers beyond the separation of the rainfall from street surfaces and the front slopes of roofs abutting upon the streets, which should be taken into surface drains, and that of passages, yards, and back slopes of roofs, which should go to the sewers proper. In this opinion I concur. Any attempt to carry out a double system in its entirety would only result in confusion and dislocation of both systems. I find that accepting this principle as a basis for comparison of the two systems in the built up area of Manchester the rainfall received by the surface water sewers and the foul water sewers under a "separate" system would be practically equal. In the outside districts a somewhat larger proportion would be received by the surface water drains, and the average proportion would probably be 60 per cent. to the surface drains and 40 per cent. to the sewers. Assuming a typical area of 1,000 acres, with a population of 40 to the acre, and a sewage delivery of 40 gallons per head, the volume of sewage at its time of maximum flow would be 266 cubic feet per minute, and the amount of rain required for a dilution of six to one would be 1,330 cubic feet per minute, equivalent to ·054 of an inch per hour on the whole area, assuming 40 per cent. of the fall to reach the sewers within the hour. Approximately, therefore, a fall of about 1-20th of an inch of rain falling in an hour, with 40 per cent. or 1-50th of an inch reaching the sewers in the hour, would dilute the sewage to the extent of six to one. Under a combined system the whole of this would go to the sewers proper, and the excess up to any amount would be passed by storm overflows into the river. Under a separate system 60 per cent. would go to the surface water drains, and to that extent the foul water subsidiary sewers would be relieved. But it might reasonably be anticipated that 1-50th of an inch is not more than ought to pass into the intercepting sewers as the "first flush," which would be so foul as to require treatment. Up to this extent, therefore, the intercepting sewers and the outfall works would obtain no relief from the "separate" system; but on this point being reached, the surface water drains might be arranged to cease delivering into the intercepting sewers, and the volume received by the latter would be the sewage plus the proportion of rain due to 400 acres of the drainage area or a dilution of about three to one. It is evident, however, that beyond this point the intercepting sewer must continue to take the rainfall from the limited area of 400 acres, as it falls, up to its maximum of five times the sewage; and therefore on the assumption of a dilution limit of six to one, the main outfall could not be appreciably reduced in size. The purification works, however, would be relieved as soon as the rain had passed its limit of ·054 per hour, and such relief would continue up to a fall of ·14 of an inch per hour, at which point the storm water overflows would come into action. Briefly, therefore, up to a fall of 1-20th of an inch per hour there would be no relief afforded by the rain water sewers, owing to the "first flush" having to go to the outfall, and for all falls betwen 1-20th and 1-7th of an inch per hour the main outfall sewer would be relieved in varying degrees, while beyond the latter point it would be called upon to take the same quantity as if the "separate" system did not exist. There is no doubt that on a very large number of rainy days this relief would be a great advantage in rendering the works less liable to be flooded by heavy flows, and in securing greater uniformity of treatment. It might be that in well-scavenged towns it would not be necessary in practice to admit the full 1-50th of an inch from the surface drains to the main sewer, and if this were found to be so, the range of relief would be more extensive, but with a dilution limit of six to one for purification purposes the maximum would still be reached on the limited area, though much less frequently. And though it is universally admitted that the first washings from the streets and roofs are of such a character that they ought to be purified, their admission to the intercepting sewer is not by any means free from difficulty and disadvantage. The "first flush" is always subject to very wide variation, both in volume and rate. Simple as the method of separation by "leaping weir" may be, it is clear that with surface drains of rapid inclination, if the separator be adjusted to a normal rate of slight rainfall, a sharp shower of short duration might conceivably carry forward the first downpour to the river, with practically all its polluting matters, and thus the method would fail in its object. It would therefore in all such cases be necessary to stop down the velocity to a very slow rate on approaching the separating chamber by flattening the gradient of the final length, or by impeding its delivery by the use of an adjustable weighted valve on its outlet, or some similar method. The separation could be effected on a principle based on the usual overflow lines, but providing for the entire closing of the connection with the intercepting sewer

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on reaching a defined amount. But it must be borne in mind that with any method for admitting the "first flush" a similar volume must be admitted as the intensity of the shower diminishes, which will be larger or smaller as the rain ceases rapidly or otherwise. There is, I think, no absolute method of separating an accurately defined amount as the "first flush," nor in any case, which is even more important, of proportioning it to the character of the liquid flowing off, and with any method which may be adopted the "first flush" may be taken time after time during the day, although the first shower of the day may to all intents and purposes have left the streets and roofs in a fairly clean condition. In towns and built up urban areas the price to be paid for the relief I have described would be the cost of a duplicate system, practically co-extensive with the streets, which might be set down generally at about one-third of the entire cost of the foul water system of sewers. In Manchester, with its 1,700 miles of streets and street sewers, such a supplementary and duplicate system, if now carried out, would cost as much as the entire interception system and main outfall sewer combined, and may well be regarded as prohibitive.

(b) The second case, viz., that of residential districts and rural areas, offers greater advantages to the separate system. The roads are generally macadamised, and their area, with open space generally is much greater in proportion to that of roofs, yards, and buildings. Watercourses are probably frequent and suitable for reception of rainfall at many convenient points. Even the early delivery of showers is not so likely to be fouled by traffic as to require treatment, and free percolation would assist dilution. With the proviso that sufficient rain is admitted to keep the sewers clean, and that efficient flushing is adopted for the foul sewers, the extreme fluctuations in flow common in the towns can largely be avoided, and in many cases the dilution limit of six to one need never be reached. The advantages of this are obvious.

(c) In cases where the sewage must be pumped at the outfall the separate system shows to the greatest advantage. More especially is this the case where it must be collected and lifted locally at several points as under the "Shone" system, for concentration at the outfall sewer. In the latter cases it is practicable to limit the volume as nearly as possible to the water fouled in domestic and trade operations, with the advantage of reducing the necessity for power to a minimum. With carefully scavenged roads, largely macadamised or gravelled, and with surface drains carried as far as possible within the curtilages of the properties, it is probable that the volume delivered at the outfall would rarely reach a dilution of three to one. But under circumstances where the sewage is pumped at the outfall, it has been estimated by competent authorities that the construction of a duplicate system would entail an expenditure seven or eight times greater in amount than any possible saving in the outfall and power at the works.

(d) In the case of tidal outfalls, there is no advantage to be gained by the adoption of the separate system, unless in those rare instances where the sewage is lifted so as to permit of discharge on a falling tide.

Cost.—In my view it may be assumed as generally the case that a separate system will entail an increase of 33 per cent. in capital cost over a combined system; and that the saving in either pumping or purification charges will not, where a fixed limit of dilution is in force, nearly compensate for the increased interest and sinking fund charges on the extra capital cost.

It would appear that the separate and combined systems can both be usefully employed, but that the conditions of various towns and districts are so divergent that it must rest with the engineer, after carefully weighing the circumstances of any particular case, to advise as to which of the two should be adopted. This was the conclusion recorded when the subject was discussed at the International Congress of Hygiene and Demography when last in session at Brussels in September, 1903.

24261. As regards septic tanks, how should they be shaped?—I consider that a long rectangle in the direction of the flow is, generally speaking, the best shape for septic tanks; as offering the best conditions under which the character of the effluent can be rendered completely uniform. Beyond the attainment of this end there is no object in unduly increasing the length in proportion to the width, and it is generally considered that a disproportionate length of travel beyond certain limits becomes objectionable, particularly when the sewage has already become well broken up in its passage through a long outfall sewer.

24262. Should septic tanks be divided into sections?—In my opinion septic tanks may well be divided into sections, so that any disadvantage arising from fluctuation in the amount of flow may be reduced to a minimum.

24263. Should they be used in series or in parallel?—I think that in order to secure uniformity in septic action throughout the body of the liquid, septic tanks should be used in parallel, in preference to being used in series. If used in series, the septic action in the final compartments is disproportionately less than that which takes place in the initial compartments. It does not appear to me that a scum on the surface is absolutely necessary, and in tanks of wide unbroken area a scum may be undesirable, as under the action of the wind it may be impossible to maintain the scum intact, and under such circumstances it is often broken up and carried away with the effluent.

24264. Should the septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—There seems to be no advantage in a closed tank over an open one as regards septic action, though something may be said in favour of the closed tank as a means of avoiding possible nuisance, and the sentimental objection to the sight of an area of sewage water. In large tanks open to the action of the wind a covering has advantages in minimising surface disturbance, but it need hardly be said that these are the cases in which a covering is most costly. Covered tanks will cost from 30 to 50 per cent. more than open ones.

24265. What do you consider the best arrangement for the "feed" and "draw-off"?—I think the best arrangement for "feed" is one in which the incoming sewage is admitted by dip pipes or valves delivering the sewage midway between the surface and the bottom. Such dip pipes should be numerous, and may in fact be arranged so closely together as to amount to a perforated inlet wall at the low level. The admission of the water may, however, be controlled by a single inlet valve on an intervening channel. The "draw-off" arrangement should be a similar perforated wall, with a channel behind the outflow cell, the openings into the channel being at about one-fourth the total depth from the surface. I think these arrangements are of value in preventing distinctive longitudinal currents through the body of the tank.

24266. At what rate is sewage, as a matter of custom, passed through your septic tanks?—Sewage is passed through the Manchester septic tanks under normal conditions at an average rate of six inches per minute, but this velocity is, of course, subject to increase proportionate to any accumulation of sludge and to increased volume during rain. The velocity at time of maximum flow during the active portion of the day is double that during the night at time of minimum flow, and 50 per cent. above that at time of average flow.

24267. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous? Why do you consider one rate more advantageous than another? Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with?—Probably the most advantageous rate of flow through septic tanks is a rate at which the entire volume of the tank is changed once in 18 hours, or (with the Manchester tank) say $3\frac{1}{2}$ inches per minute; and when this rate is increased by accumulation of sludge and by increased volume, to 18 inches per minute, it would seem to me disadvantageous. There seems to be in all septic tanks immediately overlying the septic sludge a similar stratum carrying a large proportion of finely divided material in process of settlement, with which a very slight increase in the rate of flow is likely to interfere, the effect of such increase, however, being within limits capable of adjustment in the length of the tank. It is for this reason that I think the rate of flow should be as constant as possible, and variation should be reduced to an absolute minimum within economic limits. The question of the relation between the rate of flow and the strength or character of the particular sewage under treatment is a matter rather for a chemist than an engineer.

24268. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a consideable period without cleaning and then remove all the sludge? In the latter case how often would you clean out the septic tank?—From my experience I consider that a certain amount of sludge ought to be removed periodically from septic tanks, and that it is not desirable to work them for a long period without a cleaning, and then remove all the sludge. In the latter case septic action is discontinued, and has to be recommenced at the cost of a considerable loss of time. By the removal of sludge periodically this is avoided, and tanks can be kept in use for an almost indefinite time, and in no case should the accumulation of sludge be allowed to exceed 20 or 25 per cent. of the total depth of the tank.

24269. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—It has been found possible at the Manchester works to remove large quantities of sludge from the floor of the septic tanks through pipes or channels laid on the bottom, and without any disturbance of the supernatant water, the sludge thus removed containing about 87 per cent. of water. No nuisance whatever attends the operation as thus conducted, the successful employment of which would obviate the nuisance which to some extent at times is inevitable with the present objectionable method of using manual labour for pushing the whole of the sludge by means of "squeegees" to the outlet valves. The sludge from the Manchester works is mainly taken direct to sea, but this method of disposal is, of course, only available in a limited number of cases. The method of disposal, whether by pressing, delivery in its crude state to land, or drying in lagoons to be dug out for agricultural use, must depend on the size and situation of the works in each particular case.

24270. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount as the time approaches for removing sludge from the tanks?—The suspended solids coming away with the tank liquor do tend to increase in amount as the time approaches for removing sludge; and this is my reason for advocating periodical removal, and for thinking that a stratum of 20 per cent. to 25 per cent. of the total tank depth is the maximum which should be permitted to accumulate.

24271. What amounts of suspended solids, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—I have no statistics on this point, which is rather a matter for the chemist.

24272. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—From my experience I should say that the sewage which arrives at the works in wet weather may be passed through the septic tanks to the extent of one dilution with rain; beyond this I think the increased velocity is prejudicial. The velocity is always double at least once for a certain period in the 24 hours, and wide and sudden variations are to be avoided.

24273. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank; and, if so, can you give us figures (in parts per 100,000) showing what the increase is?—This is rather a matter for analytical observations, which are not within my province, but I cannot conceive that the admission of storm sewage to a septic tank, with the increased velocity consequent upon it, can have any other effect than to increase the amount of suspended solids issuing with the tank liquor. This conviction would lead me to do everything possible within economic limits as to tank area to avoid variations in speed. I am unable to say what such an increase would amount to.

24274. May you admit storm sewage to your septic tank to an extent which raises the ordinary level of the liquid without serious detriment to the functions of the tank?—I have no personal experience on this point, but it would seem to me that such a course introduces a necessity for intermittent action, which is undesirable.

24275. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way, as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—I have not made any observations on this point, but under ordinary dry weather conditions and within reasonable limits I have not hitherto considered such fluctuation prejudicial.

24276. Have you data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints?—Our tanks at Manchester are plain septic tanks, and I have made no observations upon septic tanks filled with rough stones or flints; but it seems to me that with the latter kind of tank the removal of sludge would be a most difficult and costly matter.

24277. Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?—The Manchester tanks are very large, covering an area of about 11 acres; but they are singularly free from smell or nuisance, except possibly to a very slight extent when sludge is being cleared, and no complaints, so far as I am aware, have ever been made.

24278. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—It is desirable that suspended solids in sewage should be removed as far as practicable before the sewage is filtered, especially when the surface of the filter is not specially prepared with a layer of fine material. An endeavour should be made to approximate to 6 parts per 100,000 as a limit.

24279. How can the removal of suspended solids best be effected?—I am in favour of subjecting tank liquor to treatment through a streaming filter before putting it upon bacterial filters, and where area is not restricted I believe upward filtration supplementary to tank treatment to be valuable. But, whether upward or downward filtration be adopted, ample area and facility for cleansing is essential, as the filtering material, if efficient, soon clogs, and the volume passed rapidly diminishes.

24280. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before passing it on to filters?—At Manchester the experiment of both upward and downward filtration in connection with the tanks was tried, but the area available was found to be totally inadequate.

24281. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement? I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis?—A comparison of the relative advantages of the several methods of settlement, on the assumption that in each case the sewage is reduced to the same figure for suspended solids, is rather the subject for inquiry by a chemist than an engineer. But as to the respective advantages, apart from this basis of uniformity of results, the following observations may be of service:—

(1) Quiescent Settlement without Chemicals.—So far as my experience goes, quiescent settlement is more advantageous generally than the continuous method. A period of absolute rest, in which gravity is free to act on each suspended particle, is better than a condition in which it can only act simultaneously with horizontal movement of the body of water. But the method of quiescent settlement is rarely adopted owing to the loss of fall involved by the necessity of drawing off the body of water at the low level—whereas in the continuous method there is no loss of fall, as the level of exit is the same as that of entry. Quiescent settlement without chemicals is slower than with chemicals in the proportion of two to one, and the tank space required is therefore larger. The period generally considered necessary for quiescence without chemicals is two hours. The method is generally employed in connection with land treatment. An important advantage in the quiescent system consists in the fact that the discharge may be arranged to be automatic by the adoption of comparatively simple methods, and the necessity of constant supervision thus obviated. Care must however, be taken that sludge is not permitted to accumulate to a depth that such suspended solids are drawn off with

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the discharge. A point I wish to emphasise is that the use of tanks on the quiescent system where the level permits, coupled with automatic apparatus for filling and discharging, affords the best and most accurate method for separating a defined quantity for treatment in tanks and filters, the excess beyond which can be readily passed to special storm tanks or storm filters. With an apparatus such as that referred to, the period of quiescence should be decided by the maximum rate of flow when diluted by rain, and if this be done the use of these tanks permits a longer settlement when the sewage is foul, the period being shortened as it becomes more dilute, with obvious advantages.

(2) Quiescent Settlement with Chemicals.—In this case the disadvantage of loss of fall also applies. The quiescent period may be shortened to one-half the period necessary without chemicals. The sludge deposited will be greater in volume, and containing a greater proportion of water.

(3) Continuous Flow Settlement without Chemicals.—This method I regard as most suitable for storm water and for weak sewage at time of minimum flow. It is usually employed in connection with land treatment, and where the available fall is limited. The time of transit through the tank when used for treatment of sewage should be four hours, and the number of tanks required would be more numerous than for either of the quiescent methods. As against the quiescent system, however, the continuous flow system is open to the disadvantage that except with circular tanks and special apparatus the supernatant water must be drawn off to permit of removal of sludge, and pumped back into tanks for retreatment. There is, on the other hand, no likelihood of injury being caused by the risk of drawing off sludge along with the effluent.

(4) Continuous Flow Settlement with Chemicals.—This is the most widely adopted method where chemical precipitation is in use. The use of chemicals will generally lessen the period of stay in the tanks from four hours to two hours, and the tank liquor may be equally well purified on land or on artificial filters, either on the contact or continuous system. The average volume of sludge produced by this method will be about 20 tons to a million gallons, and the percentage of water in the sludge is usually high.

(5) Septic Tank Treatment.—The advantages of this method are the breaking down and liquefying of some portion of the organic matters and the reducing of the volume of sewage to a more uniform state for subsequent treatment on either contact beds or continuous filters. A certain amount, varying from 15 to 25 per cent. of the organic matter, is dissolved in its passage through the tank.

As to the question of nuisance, it is probable that, so far as sewage is concerned, either quiescent or continuous settlement with chemicals will involve the least liability to offensiveness, though covered septic tanks are probably equally free from smell. Nuisance arises more often in connection with sludge than sewage, especially during disturbance or removal, and as the volume of sludge from chemical treatment is somewhat greater, there may be more frequent removal necessary. All forms of tank treatment are equally liable to this, with the exception of covered septic tanks; but in all cases it is possible by the adoption of suitable apparatus for removal to minimise the evil, avoiding the disturbance of the water, as in the various types of circular tanks, and also to some extent lessening the period of exposure to the air during the process of removal. Other things being equal, pressing is the most suitable method of dealing with sludge from chemical precipitation. Sludges from septic tanks or non-chemical sedimentation are more suitable for land application. The subsequent purifications of the tank liquors will depend on the character of the sewage and its inter-mixture with trade effluents. The particular method to be employed in each case must rest with the chemist, who alone is competent to indicate the rules which should determine the choice of one method in preference to another.

Comparative Cost.

Assuming a daily dry weather flow of 1,000,000 gallons of sewage per 24 hours, with a maximum rate of 1,500,000 gallons per 24 hours, I estimate that the capital and annual cost of tanks and treatment respectively for the several systems would approximately be as follows:—

	Capital cost. £	Annual cost. £
1. Quiescent settlement without chemicals - - - - -	1,750	550
2. Quiescent settlement with chemicals - - - - - -	1,400	800
3. Continuous flow settlement without chemicals - - - - -	1,400	550
4. Continuous flow settlement with chemicals - - - - -	700	900
5. Septic tanks (covered) - -	5,500	300
Do. (uncovered) - -	4,000	300

The initial cost of machinery for sludge pressing, buildings, etc., is assumed to be common to all systems, and does not affect the comparison. It will be observed that on this estimate the system of continuous flow settlement with chemicals is lowest in point of capital cost and highest in annual cost, while septic tanks (covered or uncovered) are highest in point of capital cost and lowest in annual cost.

24282. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—I think that contact beds should, as a rule, be constructed with building materials, *e.g.*, brickwork, concrete, etc., both as to walls and flooring. In some cases, where the ground is a solid impervious clay, where the site must be excavated to such an extent as to absorb expenditure which might otherwise be available for building materials, or where for other urgent reasons economy is of great moment, the beds may be formed in the natural strata. But in such cases the works should not be regarded as permanent works, and should be charged upon revenue or current rate rather than upon capital.

24283. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency?—Within certain limits the depth of contact beds may vary without affecting their efficiency. Probably 2ft. to 6ft. are permissible limits, dependent to some extent on the fineness of the material employed, the deeper bed should have material somewhat coarser as a check on the tendency to consolidation.

24284. What do you consider is the most convenient size for a contact bed?—The most convenient size for a contact bed is such as will admit of the bed being filled in one hour at the normal rate of dry weather flow. The total area of beds, however, must always be divided into a sufficient number of units, due regard being paid to the maximum and minimum rates of flow, the increased volume to be treated in wet weather, the necessity for rest, cleaning, repairs, etc. For facility and economy of working in the Manchester scheme the beds are enclosures, each containing a net half acre of filtering surface, but as they are grouped in pairs on either side of the common supply channel, and the filling centres are opposite each other, they are, when used together, to all intents and purposes enclosures of one acre each.

24285. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—I think that the very best filtering material for contact beds, all things considered, is broken brick or stone, but these must be of the hardest character, as blue Staffordshire brick and the hard rock of the Yorkshire or Lancashire quarries. It is rarely possible, however, to provide these materials in sufficient quantity at reasonable cost, and the material which, while efficient, is least liable to disintegrate in the bed, is hard, well-vitrified furnace clinker, which can be had in practicable quantity in all manufacturing neighbourhoods. In districts where stone quarries are numerous the quarry refuse, properly broken, is suitable and not unduly expensive.

24286. What size should the filtering material be, and should it be graded in the beds?—For primary (first contact) beds I should employ a filtering medium which will pass a two-inch and be rejected by a quarter-inch mesh; and for secondary beds a medium to pass a one-inch and be rejected by an eighth-inch mesh. Grading the material in the beds increases the cost

considerably and without any corresponding advantage. The coarser material will in filling the bed always separate itself at the bottom, which may be covered with it to advantage, and it may be also piled up over the lines of the under drains.

24287. How should the bottom of the bed be constructed?—The construction of the floor of the bed will depend to some extent on its shape and dimensions. In beds which take the form of a long rectangle, the bottom should be formed with a slope from side to centre, the main discharging drain being laid longitudinally down the middle with branches at suitable intervals on each side. For beds which are more nearly square, the plan adopted at the Manchester works seems to be more suitable, in which the under drains converge to a circular collecting drain on the centre of one side. For facility of working this gives a material advantage, as the supply and discharge valves for each pair of beds are near to and opposite each other. The floor of the bed should in all cases be covered with a sheeting of concrete, in which the drains may be recessed, covered with tiles which are flush with the concrete surface. This permits of the bed draining itself absolutely clear while resting, a result never attained in cases where drain pipes are laid on the surface of the floor. In the event of the material being at any time taken out and washed, this plan facilitates its removal, and admits of the floor being swept clean.

24288. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds?—I am not in favour of putting crude sewage upon contact beds. Some form of tank treatment should be adopted; but whether sedimentation, septic tank, or chemical precipitation, will depend upon circumstances.

24289. What periods of filling, standing still, emptying, and standing empty do you consider best in practical working for primary beds and for secondary beds?—The following periods are those found in practical working to be best for primary beds:—Filling, one hour; standing full, two hours; emptying, one hour; standing empty, the remainder of the period dependent on the number of times the bed is used in the course of 24 hours. Where the beds are used for the purpose of dealing with part of the rainfall, the period of standing full and resting should be curtailed in accordance with the increased number of fillings. Secondary beds may be filled and emptied more frequently, and the whole of the above processes shortened to a considerable extent, so that where the depth of the secondary bed is the same as that of the primary one, the area may be very much reduced. Thus, if a primary bed occupies two cycles of 12 hours each, a secondary bed may very well be filled and discharged six times in the 24 hours, or three times the above rate. This appears to be the utmost practicable limit for use as contact beds, and beyond this they may be used as streaming filters. With the four hour cycle, the periods might be:—Filling, ½ hour; standing full, 1 hour; emptying, ½ hour; resting, 2 hours. The periods of filling and discharging will always be subject to modification according to circumstances, such as the age or fineness of surface, and the state of the body of the bed; for which no absolute rule can be stated.

24290. How should contact beds be filled and emptied?—I think there is no doubt that contact beds should be filled as far as possible evenly from above, and discharged in the same way from below. Lateral filling is not desirable.

24291. Have you had any experience of automatic gear for filling and emptying?—Automatic gear has not been used at the Manchester works for filling and emptying contact beds on a working scale. In very extensive works, the varying condition of the bed surface as regards its permeability is sufficient to render the operation of absolutely automatic gear very uncertain. I drew attention to this point when these works were designed, and it has since been amply borne out in practice. Forms of automatic gear, too, which are effective and constant in operation for small works, become impracticable and unreliable if applied to beds of large area. The use of any automatic gear, if efficient, will necessitate fluctuations in the cycle, consequent on fluctuations in the flow; but I cannot say from experience whether this would cause a falling off in the effluent or tend to impair the beds. Within reasonable limits I should say not. I can say from experience that the fluctuation in the flow is not nearly so important a factor as the varying state of the bed and bed surface. In large works, the main advantage of automatic gear can be secured, and uncertainty and complication reduced, by the adoption of a semi-automatic type of gear, in which the initial operation of filling is not dependent upon the automatic factor, but is regulated at will both as to time and rate according to circumstances. The whole of the subsequent operations of stopping the supply, controlling the period of standing full, and discharging the contents, are automatic. Inasmuch as it is in connection with the filling that difficulty is usually found to arise, human control is better applied at this point, and all the other operations may be absolutely automatic. Such a type of gear was tried at these works, and was, generally speaking, successful. An endeavour was also made here to secure the advantages of automatic working without its disadvantages by the adoption of electrical control of the supply to the bed, the remaining operations being automatic. In this type of gear it was intended that the whole of the beds should be operated from one common centre, and thus be under complete control. This method, too, was demonstrated to be quite practicable, and was in use on one particular half-acre bed for a long period, being operated from the engine-room about 600 yards distant. It was eventually found, however, that the apparatus was subject to derangement from the effects of ammonia and other fumes arising from the sewage, and its use was abandoned. Both supply and discharge of the beds on the Manchester works is now regulated by hand.

24292. Is the loss of capacity in contact beds in direct proportion to the volume treated, and the amount of suspended solids contained in the liquid which is put into the bed, or to the fineness or coarseness of the material of the bed, or on what does it depend?—In my opinion, the volume treated, the amount of suspended solids, and the grade of the material, are all factors in determining the rate at which a contact bed loses capacity.

24293. Can the material of a clogged bed be washed; and, if so, how can this best be done, and at what cost per cubic yard?—I have not had experience in washing the material of a bed on anything like a scale which would indicate the best method or the probable cost.

24294. How can the capacity of contact beds be best maintained?—(a) By allowing ample area, especially in primary beds, so that the volume treated per cubic yard can be kept well within the power of the bed. (b) By reducing suspended solids in the tank liquor to the lowest possible point. (c) By maintaining a fairly fine surface as far as consistent with proper aeration, and giving constant attention to removal of deposited matter from the surface. (d) By regularity in resting periods.

24295. What was the cost of your contact bed installation per acre, and how much liquid do you treat per acre in ordinary times and in storm times?—The cost of the first contact beds at Davyhulme has been £2,650 per acre. We have at present no second contact beds. The primary beds are 3ft. 4in. deep. The cost of our storm water beds (which are to some extent used as single contact beds) has been £1,500 per acre. Their depth is 2ft. 6in. The volume treated per acre varies on both classes of beds. On the contact beds proper it has ranged from 300,000 gallons per acre per day to 800,000 gallons per acre per day, and on the storm water beds from 200,000 gallons per acre per day to 500,000 gallons per acre per day.

24296. Do you find any nuisance from the treatment of sewage in contact beds? Have any complaints been made?—We find practically no nuisance from contact beds, and I am not aware of any complaints having been made.

24297. Have you had experience of continuous or percolating filters?—We have no continuous or percolating filters on the working scale at Davyhulme, and experience with them is confined to the experimental plant, as to which I am only in possession of such information as is available in the published reports.

24298. With regard to your answer to Question 24240, what is done with the contents of the pail closets or middens?—The Corporation of Manchester have large estates on the Mosses—i.e., the peat deposits of Lancashire. At Carrington Moss they have about 1,100 acres, and at Chat Moss they have about 2,500 acres, and the solid refuse of the city is taken there and used agriculturally.

24299. The municipal authorities remove it?—They remove it, certainly.

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24300. And probably there is no nuisance at all attaching to it?—Nothing more than the passing nuisance in the process of removal.

24301. Then on your reply to Question 24245 and the question of the storm overflows: at what rate do they come into operation?—As a rule five volumes of rain to one volume of sewage.

24302. Then in reply to Question 24247, you say that "the volume of sewage coming to the works during the year is approximately from 12,000,000,000 to 13,000,000,000 gallons. The amount passing away by storm overflows cannot be stated with any degree of accuracy." Can you give any kind of approximate statement of that latter amount?—I have prepared an approximate statement—I am afraid it is very approximate—but it is pretty much in this form. I do not know whether I ought to go through the whole of it. One year's average rainfall taken over three years in the Manchester area is 31½ inches per annum. The proportion of rainfall reaching the sewers—I take it approximately at 50 per cent. That gives me, with an estimated rainfall over the whole area of 31 inches, 8,432,000,000 gallons. I take 50 per cent. of that, which is 4,216,000,000 gallons. I add to that the dry weather flow of sewage taken at an average of 25,900,000 gallons per day for 365 days, which gives me 9,453,000,000 gallons. That amount of sewage and that amount of rainfall added together give me 13,670,000,000 gallons of sewage and rain which ought to come to the works. The volume we actually receive at the works is 12,940,000,000 gallons, leaving a balance of 730,000,000 gallons approximately, which presumably passes over the storm water overflows. That is the nearest approach that I can give you. Shall I give you a copy of that statement.

24303. We should like to have it, certainly.

STATEMENT HANDED IN BY MR. WILKINSON.

Manchester Sewage.

Statistics *re* Overflows.

Area of Manchester sewered (including portions of Stretford and Audenshaw)	11,800	acres
Average rainfall for three consecutive years	31.5	ins.
One year's rainfall on sewered area	8,432,943,750	gals
Proportion of rainfall reaching sewers, say, 50 per cent.	4,216,471,875	,,
Volume of sewage received at sewage works in one year	12,940,200,000	,,
Average daily dry weather flow:—		
Winter	26,481,000	,,
Summer	25,311,000	,,
Average 25,896,000 gals. say	25.900,000	,,
Dry weather flow for one year = 25,900,000 by 365 =	9,453,500,000	,,
One year's rainfall, 50 per cent. reaching sewers	4,216,471,875	,,
Total volume sewage and rain entering sewers	13,669,971,875	,,
Deduct volume received at works	12,940,200,000	,,
Total volume passed away by overflow for the year	729,771,875	,,

24304. How do you justify your estimate that only 50 per cent. of the rain reaches your sewers?—I arrive at it somewhat in this way. If you take a typical area of 1,000 acres, and assume that it is populated at the average rate for Manchester of 40 per acre, that would house, so to speak, 40,000 people. But you have to arrive at what is the probable proportion between the impervious surface from which water rapidly and fully reaches the sewers, and the absorbent surface from which probably none or a very small quantity of water reaches the sewers. Then I take the 40,000 people who would be housed upon the 1,000 acres in Manchester, and I take the congested parts of the city as a guide showing how closely the houses might be packed together so as to give an area of absolutely impervious surface—if you follow me. We have, roughly speaking, a congestion of, say, 80 per acre, and 500 acres out of the 1,000 at that rate would be occupied by houses and streets and yards which would send the water off to the sewers almost as soon as it fell, and of course a very large proportion of it. I should therefore assume that that 500 acres would deliver 80 per cent. of its rainfall to the sewers and that the remaining 500 acres on a usually accepted basis, I should say, would not deliver more than 25 per cent. Taking the 500 acres at 80 per cent., and the 500 at 25 per cent., you will find that regarded as rainfall reaching the sewers, the average is roughly speaking 50 per cent. It may be more—a little more; I would not say it is not; I made it actually 52½ per cent. when I came to go into the figures in that way. That is the only guidance I can give. A town varies very widely, even within its own limits, as to the absorbent capacity of the soils and also as to the amount of ground allocated to gardens, cemeteries, parks and whatnot; you have to average the whole lot together.

24305. Is the result, if we compare the quantity that goes to your works with the quantity that goes over the storm overflows, that whereas if the former is 100 the other is, so to speak, only about 5 or 6?—That is so: but if you compare the quantity of rain entering the sewers with the quantity going over the overflows, if the former is 100, the latter is about 17.

24306. We have had evidence of some cases where the amount is enormously greater than that. In reply to Question 24252 you say: "If a minimum addition of five volumes of rain be the lowest requisite as a dilutent in order to render storm water harmless before passing it into the river, it seems reasonable that the standard measure of dilution should be applied at the time of the maximum flow, when the foulness is greatest." From the engineering standpoint, would you consider that a larger amount than six times the volume could be brought to the works without any very serious extra expense. Could you, for instance, give the Commission an approximate idea as to the percentage of the increased cost if the sewers were made to take twelve times the volume instead of six times?—I think a dilution of five volumes of rain to one volume of sewage is the highest practicable economical limit for public bodies. To take our own case, for instance. The Manchester main outfall after the last overflow is capable of delivering six times the maximum rate. The maximum rate being given at 37 millions gallons a day, the main outfall sewer after the last overflow is capable of delivering at a rate of 222 millions a day, which is six times the maximum rate. If we were, as you suggest, to continue our main sewer undiminished in size from above the overflow down to the works, we should have to construct, roughly speaking, I suppose, a couple of miles, say 3,500 yards of the enlarged sewer in addition to the one that we have, and that might make a difference of probably £50,000. I ought to say that our main outfall sewer above the overflow is capable of taking, roughly speaking, about ten times the maximum flow.

24307. (*Sir William Ramsay.*) In your reply to Question 24260, you say that the surface water drains might be arranged to cease delivering into the intercepting sewers. Is that difficult to carry out?—I do not think so. At the time I wrote that paragraph I had in mind an arrangement of Mr. Hewson, the City Engineer of Leeds, which I came across some years ago, in which he proposed to close the orifice to the intercepting sewer entirely after a certain volume had been reached.

24308. Would that require to be done by hand?—No it would be automatic.

24309. It could be done automatically?—Yes, it could be done.

24310. There would require to be a great many automatic valves?—There would have to be at least one arrangement at every overflow.

24311. How many would that mean in a town like Manchester?—Something over 200.

24312. But it would be quite possible to do it?—It would be quite possible to do it, but I ought to point out that you would have to have the same thing on the down grade as you have on the up grade of the storm, so to speak.

24313. Quite—that is to say they would open again?—Yes, they would open again when the storm got down to a certain point; they would continue to deliver an increased quantity on the down grade of the storm.

24314. But there would be no objection to that, would there ?—No, except the increased volume at the works.

24315. Indeed, as the storm is dying off, I suppose the effluent is less noxious ?—It is less noxious, I think so.

24316. Then also in your reply to Question 24260, you say that there is no absolute method of separating an accurately defined amount as the first flush ? You would require, if such a plan were adopted, to arrange that these valves should shut at some time after the first flush had taken place. You want to collect the right flush at the sewage works, do you not ?—Yes, the first flush ought to be collected.

24317. Then you would give a pretty wide margin before your valve would shut ?—Yes. I would always act on the side of excess rather than of defect, so far as was consistent with the safety of the intercepting sewers, of course.

24318. Then in reply to Question 24279 you speak, of a streaming filter. What is meant precisely by that ? I think we understand, but I want to have an accurate description ?—By a streaming filter I imply a mechanical filter—downward filtration acting on the principle of a water-works filter or otherwise.

24319. Feeding the liquid to be filtered into the filter at one end and out at the other, or would you distribute it ?—Distribute it over the whole.

24320. It would be a very coarse filter, I suppose ?—Yes.

24321. With coarse material ?—Our storm water filters at Manchester are really streaming filters. The water can be poured on, and as fast as the water is poured on it flows away, having passed through the body of the bed.

24322. The filter is kept full all the time I suppose ?—The filter is kept full.

24323. In your answer to Question 24281, you make an interesting statement. You say, "Quiescent settlement without chemicals is slower than with chemicals in the proportion of two to one." Have you data obtained at Manchester to settle that question ?—No, not at Manchester. That is a statement in accordance with my own practice if I were designing works on either of those two systems.

24324. It is a very valuable point to know that you can really halve the capacity of your tank by chemicals ?—Yes.

24325. You increase the sludge, but you halve the capacity ?—Yes.

24326. I notice that you put the cost of septic tanks covered and uncovered not very far from each other. You give £5,500 in the case of covered tanks, and £4,000 in the case of uncovered tanks, and the cost for upkeep is about the same. I should have thought the covered tanks would have cost a good deal more than the odd £1,500 out of £5,500 ?—To arrive at those figures I took out approximate quantities, and those were the results I came to. In my reply to 24264, I have given 30 to 50 per cent. as the excess cost of covered tanks over open ones.

24327. Would that be a heavy concrete roof or a mere scaffolding ?—A steel girder roof, similar to the ordinary light fire-proof flooring.

24328. I was thinking rather of the plan at Exeter—of a heavy concrete roof ?—Thrown into arch form ?

24329. In arch form ?—Yes.

24330. You would not think that necessary ?—I do not think so.

24331. That is what made me wonder ?—I think the expense would be prohibitive in the case of very large tanks. With very large tanks your supports would take up a considerable proportion of the bulk of the tank.

24332. You would require the support of pillars ?—Yes. On the system of covered surface reservoirs practically.

24333. You refer pretty often in your answers to automatic gear. I want to ask a question as regard automatic gear. Can it be trusted; does it not want more supervision than hand labour ?—I think that by far the great majority of forms of automatic gear are open to that objection. They want looking after to see that they do work automatically, so to speak.

24334. That is what I thought ?—They are useful for small works where you cannot afford a constant service of even one man.

24335. (*Major General Carey.*) In reply to Question 24252 you say, "In my judgment the requirement of dilution by storm water up to a maximum represented by one volume of sewage to five volumes of rain is a reasonable one for purposes of special filtration, two volumes of the mixture being dealt with in the ordinary plant and four volumes on storm water filters." Is that on the basis of the maximum recorded dry weather flow ?—Yes.

24336. Further on in the same reply you say, "I am of opinion that in all local overflows the actual observed maximum and not the average rate of flow should be the determining factor for dilution." Do you consider that the actual observed maximum flow should be the basis for determining the number of dilutions in every scheme of sewage disposal for large as well as for small areas; do you think it can be made applicable throughout ?—I would not propose to apply that rule where the observed maximum is the result of the discharge of condensing water or water which was more or less pure. I would be governed by circumstances in a case of that kind for instance. With regard to large and small works I think the proportion of two volumes in the one case to four in the other is a reasonable one.

24337. On the maximum flow ?—On the maximum flow.

24338. *Per diem* ?—I think so.

24339. Further on in the same reply you say, "The best alternative in a gravitation scheme would be the provision of duplicate or multiple inlet to the works proper in connection with a regulating chamber," etc. Would not the provision of duplicate or multiple inlets to the works proper in connection with a regulating chamber be far too elaborate an arrangement to be left to the discretionary management of small local authorities, although it might be perfectly feasible for a first-class county borough ?—Yes, probably it would be. I should not be disposed in the case of small authorities te leave very much to discretion. But of course I had in mind—having been so much associated with Manchester—the cases of large works.

24340. And you have not regarded the general application ?—No, not so much. Again I ought to say that in modelling the latter part of that answer I had in mind what I think is the great desirability of limiting as far as possible the variations to the septic tanks. That is the conclusion to which I have come personally.

24341. In reply to Question 24255 you say, "Experience at Manchester seems to indicate that each storm overflow should be the subject of careful supervision, and that the volume to be admitted to the intercepting sewer should be carefully settled in each individual case." I absolutely agree, but would that be settled by the authority subject to the approval of a central authority or of some other supervising authority ?—I think that the local overflows should be controlled by the subordinate authority, and that the main overflow—the last overflow—which absolutely defines the volume to be sent to the works and treated, should be the subject of control by the central authority; that is my view. And I also think that, wherever possible, this last overflow should be provided with a suitable meter and self-recording apparatus, so that the volume can be regularly recorded, and details furnished, if required, by the central authority.

24342. I think you have already answered the point as to the extra cost which would have to be incurred in consequence of the alteration of the basis from the actual dry-weather flow to the maximum daily flow ?—Yes.

24343. There would be an extra cost, owing to the additional volume of sewage that would have to be treated ?—Yes.

24344. (*Mr. Stafford.*) In connection with the comparative cost of these different systems as given in your answer to Question 24281, apparently the cheapest system is the treatment of sewage in open septic tanks ?—That is the cheapest.

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24345. It works out the cheapest, taking the life of these works at, say, twenty years?—Of course, I should say that the estimate of cost is for tank treatment.

24346. For the treatment set down in your answer?—Yes, quite so.

24347. But is it also the most efficient, do you think?—Well, that opens up a very wide question. I should say that all round it is the cheapest, as compared with efficiency—I think so. I think you will get an equal amount of efficiency for a less cost, if I may put it in that way.

24348. It certainly is the cheapest system?—Yes, certainly it is the cheapest system; and I think it is the cheapest *pro rata* with efficiency.

24349. If you were asked to design a system of sewage purification for a small population where the question of cost came in, and was a very necessary one to consider, and you were treating a purely domestic sewage, what system would you recommend—assuming that there was no pumping—for a population of that description, say, of a small town situated on the sea, and you were able to put your domestic sewage straight into the sea? What system would you recommend, in such a case?—I think I should recommend the ordinary septic tank as we know it, supplemented by either double contact beds or percolating continuous filters with a subsequent filtration of the effluent.

24350. Would you think it necessary to have double contact in connection with a sea outfall, where there was no question of shell fish?—Well, I have a case in mind where single contact with a septic tank has not proved quite satisfactory, even with a considerable concession as regards the effluent.

24351. Would you, under any circumstances, allow the local authority to, or suggest that they should put the septic tank effluent into the sea without any further treatment—to put it in direct?—Something would depend, in that case, on the point at which you delivered it. If it were anything in the nature of a land-locked harbour, or anything of that kind, I certainly should not propose such a thing; I think in that case there ought to be some form of supplementary treatment.

24352. But if there was a fair scouring of the tide, would you?—And an outward current—I think perhaps in such a case as that it might be reasonable, but it would have to be under only the very best conditions.

24353. But you would, in certain conditions, allow that?—Just as I think there are conditions where there is no danger of contaminating shell fish, so there are places where the conditions are of the very best where you can deliver screened sewage. I think those cases are very rare.

24354. Yes. Now take the same case and apply it to a tidal river: what system would you advise there?—On a tidal river I think you ought to adopt pretty well the full measure of treatment which you would apply inland.

24355. On a tidal river?—I think so. Of course, something depends on how far up or down the tidal river the works might be.

24356. Then the question arises: what would you adopt inland?—Exactly what I have described as the septic tank, double contact beds or fairly deep continuous filters, followed by subsequent filtration—sand filters or something of that kind.

24357. That is assuming the river is used lower down as a drinking water?—Yes. My view is that all places, with rare exceptions, should apply adequate treatment to their dry weather flow. Beyond this, varying concessions might be made, ranging from total exemption on tidal waters under proper conditions, to a full measure of storm water treatment on inland streams. Manchester is carrying out its present works to obviate pollution of the estuarial waters of the Mersey.

24358. (*Colonel Harding.*) On the point of the comparative cost of settlement raised by Mr. Stafford, I would like to ask you a question or two. You have given us certain figures as showing the comparative cost, in your reply to Question 24281?—Yes.

24359. Comparing, for the moment, only settlement with chemicals with septic tank settlement, it is necessary, is it not, in order to get at a single figure of comparison, to capitalise the annual cost. What is the number of years that you reckon in such calculations—thirty?—Well, yes, I suppose so; I should take from twenty to thirty. In some cases I should take the one and in some cases the other.

24360. Suppose, for the moment, we take thirty. Taking the cost which you give for settlement with chemicals the annual cost of which is £900, multiplying that with thirty, we get £27,000?—Yes.

24361. If you add to that the capital cost which you put down as £700 that gives you a figure of £27,700, does it not?—Yes, £27,700.

24362. If we take the figure for the uncovered septic tank we have a larger capital cost, and a smaller annual cost. If we multiply the annual cost of £300 by thirty, we get £9,000?—That is so.

24363. If we add to that the capital cost of £4,000 we get a total of £13,000?—That is so.

24364. So that really the two figures £27,700 for chemical settlement and £13,000 for septic tank settlement are comparative figures?—These are comparative figures as near as I can give them. It makes an extraordinary difference I admit.

24365. One is about one half of the other?—Yes.

24366. But must we not take other matters into consideration also in comparing the two processes. For instance in the case of chemical precipitation, although the cost of precipitation itself is shown to be double, there has to be considered that very little suspended matter goes forward to the filters and that therefore the cost of filtration will be considerably less?—That is so.

24367. On the other hand with the septic tank treatment so much suspended matter goes to the filters that the cost of filtration will be relatively more?—Yes, that would be so. As I remark I have not taken that aspect of the matter into account.

24368. But it is necessary to take it into account?—Yes. In a full review of the comparison it would be.

24369. So that we must not look at the figures which you have given us as by any means determining the cost?—Only so far as the tank treatment is concerned.

24370. The other is necessarily connected with it?—Yes.

24371. Now let us go back to the question of storm waters. If the total volume of your dry weather flow treated during the whole year is represented by the figure 100, what do you suppose would be the increased figure representing the dry weather flow plus the treatment of five volumes of dilution?—If the total volume which comes to our works is so much——

24372. No. If the total amount of your dry weather flow is represented by 100 for the whole year, what would be the figure for the dry weather flow plus five dilutions, taken for the whole year?—Our dry weather flow daily may be taken at 26,000,000 gallons.

24373. That gives you 9,500,000,000 gallons for the year?—Roughly speaking that is so.

24374. If you dealt at Manchester with six volumes, what do you suppose to be the total volume that you would deal with; would it not be somewhere about 13,000,000,000 or 14,000,000,000 gallons?—Yes, I should say it would be.

24375. Is it a point to which you have given any personal attention?—As to what volume we should actually have, supposing we treated it at the rate of six volumes?

24376. Yes?—I do not know that I have gone into it so closely as to arrive at an absolute figure.

24377. I asked Dr. Fowler that question, and he gave it as his opinion that the relative figures would be 150 and 100; that is 100 for the dry weather flow and 150 for the dry weather flow plus five volumes?—That is practically our figure of 13,000,000,000 gallons—9,500, gallons plus 50 per cent. would be roughly from 13,000,000,000 to 14,000,000,000 gallons.

24378. May I put it in another way. Do you think that the 13,000,000,000 gallons which actually comes to your works represents roughly six volumes of the dry

weather flow?—I think it does. In accordance with the statement that I have put in we receive actually 13,000,000,000 gallons and we send 700,000,000 gallons over the overflows, which presumably do not act until there are five dilutions.

24379. That is another point to which I am coming. You are able to say that you think an addition of five volumes at times during the periods of rain represents for the whole year the treatment of about 50 per cent. more than the dry weather flow?—Probably it does.

24380. It is a very interesting question for the Commission to consider. What would remain to go into the stream untreated if all the local authorities dealt with six volumes, that is to say with five dilutions. We are under the impression that treating five dilutions, that is six volumes of dry weather flow—would not be by any means treating the whole of the storm sewage, but that there would be a great quantity going into the river by the overflows. I am a little staggered by what you tell us that in the case of Manchester, when you deal with the six volumes you deal practically with the whole of the storm water, because what goes over the overflows into the river beyond that is quite insignificant, namely 729,000,000 gallons in the whole year?—That is what I have arrived at as the probable figure. I think that the period during which overflows are supposed to act and the conception of the volume which really goes over them is really very much exaggerated.

24381. After carefully considering this matter you say to the Commission that you believe that at Manchester, when you have dealt with six volumes of the dry weather flow you have dealt with practically all the storm waters, and that what goes into the river by the overflows is quite insignificant?—I do not think it will be considerable.

24382. But you suggest that it is quite insignificant, namely 729,000,000 gallons in the whole year?—Two million gallons per day.

24383. Which is less than one-tenth of the dry weather flow?—That is so; that is after you have passed the six volumes dilution.

24384. You do not hesitate to express that opinion?—That is my opinion, and I have reason to think it well-founded. The rainfall diagrams for 1903 and 1904, one of which was a very wet and the other a very dry year, show that the rate of ·06 of an inch per hour was exceeded in Manchester during an average of 92½ hours per annum. At the same time, the sewage flow diagrams show that the maximum rate of 156 millions was exceeded during 90 hours per annum. The one is thus confirmatory of the other, and it seems clear that during those years the overflows only acted during 1·05 per cent. of the total time, also that the action was produced when the rain exceeded a rate of ·06 per hour. The observations of the late Mr. Santo Crimp on the London sewers in 1890 and 1891 were very much in accord with this. He found the percentage of the total time to be 1·90; but the London sewers were designed to take less storm water than the Manchester sewers, and hence the overflows would act more frequently. In either case the time of action is very short, and though of course this affords no guidance as to actual volume, yet it has some bearing on the question. But the rainfall diagrams for 1903 and 1904 further show that the total rain on the Manchester area, over and above a rate of ·06 per hour (the presumed overflow limit) averaged 1000 million gallons per annum. When a deduction is made for the volume not flowing off to the sewers, this figure does not differ widely from the 730 millions; especially bearing in mind that *pro ratio* a larger quantity flows off on the heavier falls than on the lighter ones. I am justified therefore in thinking that the volume given is likely to be fairly correct, and that the quantity passed to the streams over a 6 to 1 dilution (on the average flow) may be taken at about 10 per cent. of the total fall, and about 20 per cent. of the fall reaching the sewers. But there is room for much more extended observation on the subject: on which available information is somewhat meagre and obscure, so that absolute figures are not possible.

24385. You make a suggestion that the amount of storm water that should be dealt with should be calculated on the basis not of the average daily flow but of the maximum daily flow?—Yes.

24386. But according to your view there will be scarcely anything in the way of overflows if you are going to take it on the maximum?—If you are going to take it on the maximum we shall undoubtedly have an increased volume at the works beyond what I have said, the 50 per cent.

24387. No; taken on the maximum?—We take it on the average.

24388. No. According to what you have been telling us there are only about two million gallons a day that go over the overflows?—But our overflows are fixed to the average.

24389. Then the calculation is based on the average?—That is so.

24390. If you are going to base your volume of storm dilutions upon the maximum you will not be able to deal with much more because the volume that passes over your overflows is so trifling that there will not be the stuff to deal with if you base it on the maximum?—Of course if we base it on the maximum we shall have to raise our overflow sills.

24391. As so little goes over now when it is based on the average it will make very little difference, will it?—Of course it may not make a very wide difference. We do not know precisely, you see, what is the aggregate length of the storm showers that come.

24392. Do you really think it worth while to fix it on the maximum. You point out that when you base it on the maximum it really means that when the minimum is flowing you are dealing with twelve volumes, and at such times there is less impurity so that it really mean twenty-four times?—That is so.

24393. You suggest that yourself?—Yes, for purposes of comparison.

24394. Seeing that that is so, and that the volume of sewage to be dealt with is so large, is it not desirable to base it on the average and not on the maximum?—If it is right that dilutions should be carried to the point of five or six to one as I have pointed out at the time of the maximum flow if your overflows are set to the average you are passing sewage away with a dilution of only three to one.

24395. But when the minimum flow is on you are passing into a dilution of twelve to one?—Yes.

24396. You must set one against the other?—Yes; you must accommodate yourself to both.

24397. In Manchester six times your dry weather flow means 156 million gallons that you would be dealing with?—On the average.

24398. Six times your maximum flow is 222 million gallons?—Yes, that is so.

24399. The difference between those two figures which you would have to treat at times is very considerable. Is it financially practicable to do it?—These figures only represent the rate for a time which may be only a couple of hours or even less. My investigations would lead me to conclude that with overflows adjusted to the maximum instead of the average, the additional volume of rain admitted to the sewers would not be more than 250 millions per annum, or about one-third of the 730 millions, and about 6 per cent. of the total rain supposed to reach the City sewers. This would represent about 2 per cent. of the annual volume of water now going to Davyhulme.—If, as in my reply to 24252, the subsoil water were allowed for at the final overflow, this excess would be reduced to about 120 millions.

24400. We are to take it that in your view and in the conditions which obtain in Manchester you think it practicable financially for Manchester to deal with 222 million gallons rather than with 156 million gallons?—For a limited time. I cannot conceive it right—if a limit of dilution is desirable at six to one, it does not seem to me to be right to reduce it to three to one.

24401. I should be disposed to agree, as to the necessity from the point of view of preventing impurities going to the river; what I want to get at is how far it is practicable for a local authority to carry out so large a responsibility. You think from your knowledge of Manchester that it is practicable?—I think it is practicable providing it is done somewhat on the lines I have indicated.

24402. Do you claim that there may be left to the authority the large discretion which you mention to

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modify that on their own account?—In the night flow, yes, when the sewage is below the average.

24403. If you call upon them to treat the dilutions based on the maximum, at times of the minimum you must give them a large discretion?—Yes.

24404. That is rather dangerous from the administrative point of view, is it not. Would it not be simpler to base it on the average flow and let it be a constant condition?—Our observation goes to show at Manchester that at times with the overflow set to the average you do get a fearfully foul liquid. Another thing which struck me at Manchester and which I could not account for until I came to consider this question was this; we found that some of our overflows acted even in dry weather.

24405. That is due to the subsoil water?—The accession of a large volume of trade refuse when the sewage is on is very serious.

24406. That would be a very exceptional condition, would it not?—I think it is, at any rate it does happen. I was puzzled to account for it until I found out that with the overflow set at the average the dilution of the maximum may very easily be attained by the simple addition of an extra amount of manufacturers' refuse.

24407. In connection with the removal of sludge from septic tanks I am interested to see that you recommend that it should be done frequently with a view to maintaining a constant capacity in the septic tanks?—Yse, I think it ought to be done regularly.

24408. You say that at Manchester you find it quite practicable to remove from the floor of the septic tank or perhaps the channel laid at the bottom a certain portion of it frequently?—Yes. I may say in connection with that answer that sometime back about the beginning of March we did remove about 250 tons in the course of an hour from the floor of a flat-bottomed tank, and it was returned as containing 87 per cent. of water, so that that was fairly stiff sludge.

24409. I suppose that what you do is to open the valves and let the sludge run out until it appears to be coming all thin and then to stop it?—Yes.

24410. And as an engineer you suggest that that is quite practicable?—Yes, it is.

24411. In your answer to Question 24263, you express a preference for septic tanks in parallel?—Yes.

24412. On the other hand, you say that the septic action in the final compartment is proportionately less if they are worked in series?—I think it would be.

24413. Is not that rather the point that you are aiming at in Manchester. Dr. Fowler told us that by having a sort of final compartment of a septic tank from which you could remove more frequently the suspended matter accumulating on the floor you would get less suspended matter in the effluent. Is not that rather an argument in favour of having the tanks in series?—I have not thought so hitherto. But I have always understood that Dr. Fowler's idea in regard to the final compartment and the removal of sludge from it was really a question of the removal of the so-to-speak worked-out sludge; that is to say, sludge which was mainly inorganic and had not so much bacterial life in it. That is what I have always understood to be his reason.

24414. In your answer to a later question you suggest that other things being equal the pressing of sludge is the most suitable method of dealing with it?—Yes.

24415. Have you any experience of the burning of sludge cake?—No, not from close experience, but I have been at several places where it has been done. I visited the works at Ealing some years ago, where they burnt it in a crude condition.

24416. What do you mean by a crude condition?—It was simply delivered with ashes into a destructor furnace and burned as sludge.

24417. Without being first pressed into cake?—Yes.

24418. Have you any reason to think that the burning of sludge cake would give rise to any appreciable nuisance?—I have always been under the impression that at Ealing they found it necessary to put in a special cremator to dispose of the fumes. Unless you had a very tall shaft I am afraid it would.

24419. You think it would be quite practicable to deal with it in that way by burning?—It would be quite practicable to deal with sludge cake by burning.

24420. Do you think that destructors can be so arranged as to burn the cake without producing any more nuisance than the action of an ordinary destructor dealing with town refuse?—I do not think my knowledge would enable me to make a comparative statement as to how much nuisance would be likely to arise from the burning of sludge as against the destruction of ordinary dry refuse.

24421. Would you not be inclined to think that it would be less—that the burning of sludge cake would give rise to less nuisance than the burning of garbage?—I should think it would be less than the nuisance caused by the burning of garbage, but whether it would give rise to less nuisance than the burning of ordinary dry street sweepings and that sort of thing I do not know. I should think that in that case it would be rather the other way.

24422. Would you consider the burning of sludge cake to be a practicable solution of the sludge difficulty in places inland where they are not able to put it upon land or to send it out to sea?—I doubt whether it would be any better than pressing it.

24423. But when you press your sludge you have an enormous quantity of pressed cake and the question is what is to be done with it. I suggest that it may be burnt; and I ask whether you think that is practicable?—Do you mean in preference to putting pressed cake on the land.

24424. Yes?—I have not thought whether it would be worth while going to the expense of burning it, because it would involve additional expense undoubtedly.

24425. You have not really gone into the financial side of the question?—Not as regards a comparison of those two methods.

24426. But you do not think it would give rise to a nuisance, so far as your experience goes?—I do not think it would give rise to a nuisance, but I think that the best place for pressed cake is the land.

24427. Would you suggest in what way it should be applied to the land. Take an authority producing 150 tons of pressed cake a day; how would they apply it to the land?—The difficulty is with the seasons.

24428. Yes?—That is the only difficulty so far as I know.

24429. That involves that in certain seasons of the year you must store your cake until it is wanted?—That is so.

24430. And does not the storage of the cake involve a greater nuisance than the burning of it?—No, I do not think stored sludge cake is really offensive from my experience of it; it may be possibly in wet weather, but in dry weather I do not think it is.

24431. But you have no experience to enable you to express an opinion as to how much land might be necessary to take up say 100 tons a day of pressed cake?—No, I could not say that. I may say that the estates of the Corporation at Carrington and Chat Moss absorb the solid refuse of the City in the shape of nightsoil, sweepings and garbage at the rate of about twenty tons per acre per annum, and at the same rate, of course, some 1,800 acres would be required for 100 tons per day of sludge cake. But I should think suitable land would take more than twenty tons per acre; perhaps double that amount even on grass land, and very much more on arable land if ploughed in.

SEVENTY-EIGHTH DAY.

Wednesday, 17th May, 1905.

PRESENT.

The Right Hon. the Earl of Iddesleigh (*Chairman*) presiding.
Major-General Constantine Phipps Carey, C.B., R.E.
Colonel T. W. Harding, J.P.
Sir William Ramsay, K.C.B., F.R.S.
Mr. T. J. Stafford, F.R.C.S.I.,
Mr. F. J. Willis (*Secretary*).

ALSO PRESENT.

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. George Reid, M.D., D.P.H., Medical Officer of Health, Staffordshire County Council, called in; and Examined.

Mr. George Reid, M.D., D.P.H.

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24432. (*Chairman.*) You have prepared a statement which we will take as read?—Yes. Many of the questions submitted to me by the Commission have reference to specific sewage disposal works, and, as my experience is derived from various sources, I propose to confine my answers to such questions as have a general application, referring to my knowledge of particular works only in so far as may be necessary in support of my opinions and conclusions.

SEWAGE.

Question 19. *Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise? If so, would you kindly tell us what your difficulties are?*

As regards trade effluents, those of which I have had most experience are the following:—

(A) Acid waste from galvanising works.

(B) Brewery waste.

(C) Chemical waste from works for the recovery of ammonia from gas liquor.

(*a*) As regards acid waste from galvanising works, two liquors have to be considered, namely:—(1) spent acid, and (2) wash water.

In certain cases, such as Birmingham, where the volume of acid waste is trifling compared with the volume of sewage, it is found to be practicable to deal with the sewage containing both spent acid and wash water by ordinary methods, but in several cases in Staffordshire—Wolverhampton for example—where the proportion of such waste to sewage is very much greater, special methods of treatment, and certain restrictions as to discharging into the sewers are found to be necessary.

In such cases, as regards *spent acid*, the manufacturer should, in my opinion, be called upon to treat it before discharging it into the sewers, but in the case of *wash water*, no special treatment need be enforced, provided the manfuacturer gives an undertaking not to discharge such liquor in bulk at considerable intervals, but more or less uniformly throughout the day, and also consents to the works being inspected by responsible officers of the authority from time to time at reasonable hours.

Even under such conditions, however, the sewage in certain cases will not be amenable to treatment entirely on biological lines, but must be neutralised by the addition of lime, followed by treatment in precipitation tanks, as a preliminary to further disposal by land or artificial filters.

This, of course, involves dealing with a large amount of sludge, as in the case of ordinary sewage when chemically treated.

It is not desirable that even treated waste pickle or wash water should be discharged into a stream direct; facilities, therefore, should in all cases be afforded for discharging such waste into sewers after treatment to the required extent and under the conditions suggested.

According to Mr. Jones, the county analyst of Staffordshire, the proportion of free acid in wash water compared with waste pickle is, roughly speaking, about one-tenth, but in volume the former is probably four or five times greater than the latter.

When the acid used is hydrochloric acid the pickle contains from 1,000 to 2,000 grains per gallon of free acid, and from 5,000 to 7,000 grains of iron. In the case of sulphuric acid waste pickle the amounts are from 1,200 to 2,000 grains free acid, and from 7,000 to 9,000 grains iron.

Wash water, on the other hand, contains from 150 to 200 grains per gallon free acid, and from 50 to 150 grains iron.

(*b*) As regards brewery waste, when present in considerable quantity in sewage, while such sewage is amenable to bacterial treatment throughout, probably a high class effluent can only be obtained by means of a deeper filter than is usually found necessary; or, better still perhaps, by double filtration through shallower filters. The nuisance resulting, however, from septic tank effluvia, or from sludge disposal if chemical precipitation is the method of preliminary treatment adopted, is so great that in the case of sewage disposal works situated in close proximity to dwellings, special precautions must be adopted to counteract it.

As an example of this nuisance difficulty, I may mention the sewage disposal works of Stone, an urban district in Staffordshire, with a population of about 6,000, where brewery waste constitutes nearly two-thirds of the sewage flow. In this case the existing works (chemical precipitation and polarite filtration) are inadequate in themselves; but, apart from that, the nuisance experienced, especially in the summer months, by residents within 250 yards of the works is considerable.

By means of an experimental plant, I was able to show that, so far as actual disposal of this sewage was concerned, septic tank treatment, followed by double filtration through filters each 3 ft. 9 in. deep, would give satisfactory results, but, having regard to the situaton of the works, I advised the Authority that the adoption of special precautions would be necessary in order to prevent nuisance from smell. The remedy I suggested was the covering of the septic tanks and the cremation of the gases evolved, the effluent being conveyed to the filters in closed pipes and applied by movable distributors, rather than by sprays or troughs, to insure that the smallest possible area of tank effluent should be exposed to the air.

(*c*) As regards ammoniacal liquor waste, if present in considerable quantity, it is impracticable to deal with the sewage by any known process, owing chiefly to the high oxygen-absorbent property of such sewage. Also, the effluent, in itself, is poisonous to fish life. This I found to be the case at Oldbury, where the ammoniacal waste equals about one-tenth the dry-weather sewage flow, and the Staffordshire County Council obtained an Order in Court against the District Council in consequence. In this case, had it been necessary, the County Council were prepared to show that the waste in question could be dealt with at a reasonable cost, if not at a profit, before being discharged into the sewers.

Question 24. *Does the strength of sewage vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of the final effluent to a marked degree?*

So far as the varying strength of sewage from hour to hour and on different days of the week is concerned, I have no data to enable me to answer this question, but, while I have no doubt the strength does vary considerably, in the absence of trade waste in considerable quantity in the sewage, I do not find from my numerous records of analyses that the quality of the effluents varies materially if the works are efficient in every respect.

Question 25. *How do you think "strength" of sewage as affecting purification is best expressed or measured?*

I think the best indices of the "strength" of sewage from a disposal point of view are the albuminoid ammonia

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and oxygen absorbed figures, but I have previously given evidence on this point.

Storm Water Sewage.

I have already dealt with most of the points under this heading in my previous evidence, but as the questions now put are more detailed and specific, I desire to supplement certain answers I then gave.

Question 29. *Do you find that the amounts of suspended solids are increased or diminished in times of storm ; and can you give the Commission the figures at the end of each hour during a storm of some hours duration ?*

I have not got sufficient data to enable me to express a very definite opinion as to the effect of rainfall upon the amount of suspended solids from hour to hour.

My practice in recording systematic analyses of sewage, sewage effluents, and river waters, is to note the rainfall in the particular locality the day before, the week before, and the month before the date of collection of the samples ; also, in the case of streams, I record the approximate flow at the time of collection.

On looking through my records, which are very numerous, extending over a period of fifteen years, the impression I form is that in populous towns, rainfall, especially following a dry period, has the effect of greatly increasing the suspended solids, while in the case of less populous places, where the street traffic is not so great, this is not the case.

As bearing upon this question, I have prepared a table showing the suspended solids, albuminoid ammonia, and chlorine figures under different conditions of rainfall in the case of three Staffordshire streams, indicating also the volume of flow in each case. (See Table I.)

In selecting from my records the three streams in question for this purpose, I had regard to the population draining into each, and the relationships between sewage flows and the normal flows of the streams. I have also indicated in the last line of the table the approximate flows of the streams at the time of collecting the samples.

This table may be looked upon as supplemental to the table I prepared for the purpose of my evidence on a former occasion.

Question 31. *What is the character of the liquid part of the sewage in storm times ?*

Bearing upon this question, the figures set forth in Table II. may prove of interest, as showing the degree to which the suspended solids in sewage add to the impurity of the liquid. It is true that the samples in question were taken from streams. but they were highly-polluted streams, in fact it may be said that during dry weather the volume of sewage compared with stream water amounted to from one-fourth to one-half, so that from this point of view, the samples may be looked upon as sewage diluted to the extent indicated.

Question 41. *Do you consider that in certain circumstances this liquid (road drainage) should be purified ?*

The road drainage in the case of populous towns, where the natural outlet is into small streams, is certainly highly polluting, and I think it would not be unreasonable to require in such cases that the liquid should be subjected to at least partial subsidence before being discharged into a stream.

Settlement by Sedimentation alone.

I have had but little experience in the preliminary treatment of sewage by sedimentation alone, the method in the case of nearly all the works of which I have knowledge being one of the following, viz., chemical precipitation, septic tank treatment, primary filtration, and contact beds.

Chemical Precipitation.

Question 53. *Have you had any experience as to the chemical precipitation of sewage ?*

I have had considerable experience as to the chemical precipitation of sewage.

Question 54. *Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks ?*

I am satisfied that sewage from which the solids have been removed by the aid of chemicals, is, if anything, more readily purified by subsequent filtration, than sewage from which the solids have been removed by settlement or passage through septic tanks.

In certain cases, as I have already indicated, for example, when the sewage contains galvanisers' waste, chemical precipitation is essential.

In Table IV. the results of filtration after chemical precipitation will be seen in the case of Lichfield and Wolverhampton, and on an experimental scale in the case of Tipton.

Question 55. *Have you tried various chemicals ? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage ?*

My experience has been mostly confined to "alumino-ferric" and lime as precipitants, but of course in the case of sewages containing galvanisers' waste, lime only is necessary.

I cannot give any comparative data with regard to the cost of different chemicals. "Alumino-ferric," being a proprietary article, is costly, and I do not think that the results obtained are better than those from sulphate of iron (with lime), which is much cheaper.

"Alumino-ferric" in cakes is convenient in the case of small works, where, if it be placed in cages in the sewage channel, little attention is necessary.

Question 56. *What is the most effective way of adding chemicals ?*

The most effective way of adding chemicals is in soluble form.

Question 57. *What is the average analysis of the liquor from your precipitation tanks ? What length of time does the sewage remain in the tanks ?*

In Table III. I have given the mean figures of my analyses of typical chemical precipitation tank effluents in this county, the capacities of the tanks, population, and dry-weather flow of sewage, &c., being given in each case.

Question 58. *What is the character of the suspended matter in such liquor ?*

I have not made any special analyses to show the character of the suspended matter in chemically precipitated effluents.

Question 59. *Is it necessary to add further chemicals to the sludge before it can be dealt with ? If so, for what reasons, and what chemicals are used and how are they added ?*

It is the usual practice to add lime to the sludge in cases where it is treated in filter presses, owing to the mechanical difficulty arising from clogging of the cloths if lime is not added.

The addition of lime not only facilitates the process but enables a drier and firmer cake to be formed.

In the case of Wolverhampton, the lime, slacked and screened, is introduced slowly into the sludge ram while it is filling, and washed down by liquor from the filter presses, the quantity added being from 0·4 to 0·5 cwt. per ton of pressed cake.

Question 60. *What is the manurial value of the sludge obtained by the chemical precipitation of sewage, and will farmers take it ?*

I believe the manurial value of sludge obtained by the chemical precipitation of sewage is very small. Farmers, as a rule, will undertake to remove the sludge, but they generally refuse to pay anything for it, although in some cases 1s. a load is paid.

Question 62. *Do you find any nuisance from the treatment of sewage in chemical precipitation tanks ? Are complaints made ?*

So far as treatment of the sewage in the tanks is concerned, little or no nuisance need be experienced, provided the sludge is removed at short intervals ; the disposal of the sludge, however, is frequently attended with nuisance to persons living in the locality, but this is a question which will be dealt with later on.

Septic Tanks.

Question 63. *How should septic tanks be shaped ?*

Septic tanks should, I think, be longitudinal in shape.

Question 64. *Should they be divided into sections ?*

There is no need, in my opinion, to divide septic tanks into sections, unless in cases where separate detritus tanks are not provided, in which case a section of the septic tank should be utilised for such a purpose.

Question 65. *Should they be used in series or in parallel ?*

I think septic tanks should be used in parallel.

Question 66. *Is a scum necessary or desirable ?*

In my opinion, the formation of a scum is not necessary, and it appears to be immaterial whether such is formed or not.

Question 67. *Should the septic tank be closed in, and if so, what advantages does a closed tank possess over an open one?*

I do not think there is anything to be gained by closing in a septic tank, except in cases where, from its situation, it may give rise to nuisance, calling for special precautions as regards ventilation and, possibly, the cremation of the offensive gases.

Question 68. *What do you consider the best arrangement for the "feed" and "draw-off"?*

Both the "feed" and "draw-off" should, I think, be by means of a submerged inlet and outlet extending along the whole width of the tank.

Question 70. *What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous? Why do you consider one rate more advantageous than another? Do you think that the rate of flow should depend on the strength or character of the particular sewage which is being dealt with?*

The question of the rate of flow through septic tanks is one concerning which further information, the outcome of practical experience, is desirable. Personally, I think that in the case of ordinary domestic sewage, the usual tank capacity of 24 hours dry weather flow may be considerably reduced, say to from 14 to 16 hours.

Question 71. *Is it possible to "over-septicise" a sewage, and if so, for what reasons and how is the "over-septicising" rought about?*

s While I have had no experience of the treatment of over-cepti ised effluents, I can quite understand that the nitrifi-bation of such might present difficulties. Certainly, from the point of view of possible nuisance, it is desirable that the septic process should be cut short as soon as may be found to be practicable.

Question 73. *Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?*

I think that septic tanks should be worked for as long a period as possible without removing the sludge, that is, if adequate accommodation has been provided for the deposition of the detritus.

Question 74. *In the latter case how often would you clean out the septic tank?*

I think a septic tank should be worked without cleansing until such time as its available capacity is materially diminished by the collection of sludge.

Probably this period will be governed by the quality of the sewage, but, as a case in point, I may mention that I have known a tank to be in continuous use for three years without showing any need for emptying, and on being emptied at the end of that period, merely to ascertain the actual amount of sludge then in the tank, it was found that the deposit was really immaterial.

Question 75. *How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?*

As septic tanks need only be emptied at long intervals, a portable pump would answer the purpose, the fluid part being pumped back into other tanks in use, and the sludge pumped on to land.

The character of the sludge from a septic tank is such that no nuisance arises from its disposal.

Question 78. *Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?*

I am not prepared to answer this question; it can only be answered by careful observations being made on works which have various sized tanks relative to the dry weather flow.

Question 82. *Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor?*

Relatively speaking, chemically precipitated sewage is in my experience so free from suspended matter that I have no data enabling me to say whether it would be more or less amenable to treatment than septic tank liquor or settled sewage supposing it contained an equal amount of suspended solids. I am satisfied, however, that in practice chemically precipitated sewage is more readily dealt with by subsequent filtration than either of the others because of the comparative freedom from suspended solids, while, at the same time, sufficient septic action has taken place during the process of precipitation.

Question 83. *Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?*

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I think that a material reduction in oxidizable organic matter in solution takes place by septic tank treatment.

Some idea of this may be gathered from the figures of analyses of the sewage and septic tank effluents of Hanley and Pelsall, set forth in Table IV. In the case of Tividale, on the other hand, it would not be wise to draw any conclusions, as the figures relate to only one sample of sewage, which could not be taken as the standard of comparison with the mean of the five samples of septic tank effluent. In considering this matter in the light of the figures I have referred to, it is true that the analyses in all cases were made after shaking the samples; still, the reduction in the organic impurity in the tank effluents is far greater than could be accounted for by the removal of suspended solids effected by the tank.

Question 84. *Have you any data on the relative value of (a) plain septic tanks, and (b) septic tanks filled with rough stones or flints?*

I have not got sufficient data to enable me to express a very positive opinion regarding the value of plain septic tanks as compared with such tanks filled with rough stones or flints, but from the experience I have had, I am strongly inclined to the opinion that the latter tanks have no advantage over the former.

Question 85. *Do you find any nuisance from the treatment of sewage in septic tanks? Have any complaints been made?*

If the septic action is continued longer than is necessary, any nuisance which may exist is intensified, and, in any case, the distribution of septic sewage on filters, if the works are situated near dwelling-houses, is likely to cause nuisance, although the risk is greatly lessened by adopting a distributor which exposes as small an area of tank effluent to the atmosphere as possible.

Tanks in General.

Question 86. *Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?*

I certainly think that the suspended solids in sewage should be removed as far as practicable before filtration. A practicable limit in the case of a septic tank effluent should, in my opinion, be from five to eight parts per 100,000, and in the case of a chemically precipitated effluent, from two to three parts.

It will be seen from the records of suspended solids in the case of the examples given in Table No. IV. that all came within these limits.

Question 87. *How can the removal of the suspended solids best be done?*

Undoubtedly the best way of removing suspended solids is by chemical precipitation, but, of course by such a method, the question of sludge disposal becomes more difficult, and, together with the provision of chemicals, adds considerably to the cost. For this reason, and in view of the fact that the suspended solids in septic tank and primary filter effluents do not render the sewage incapable of final purification, there is no need to use chemicals under ordinary circumstances. (See also answer to Question 123).

Question 88. *Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?*

I have had no personal experience of any mechanical device for freeing tank liquor of suspended matter, but in Derbyshire straining by means of upward-flow filters has been adopted, I believe, with advantage, and at the Birmingham Tame and Rea District Sewage Disposal Works, tanks on the Dortmund principle have lately been under trial with this object.

Question 89. *What other (if any) method of dealing with tank liquor before delivering it to filters do you regard as necessary or advisable?*

Personally, I am of opinion that chemically precipitated sewage can with impunity be dealt with in fine-grain filters, and in the case of septic tank effluents, provided the suspended solids do not exceed the limit I have suggested, no difficulty need be experienced from treatment on similar filters.

In the practical working of such filters, it would seem that the suspended solids are held back by the top layer of the filter where they are digested and all that is necessary to prevent clogging, so long as the filter is not overtaxed, is that the surface shall be periodically forked and raked.

Question 90. *May I ask you to put before the Commission a full statement of your views as to the comparative*

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cost and relative advantages of the various methods of settlement. I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis.

The only methods of sludge removal concerning which experience enables me to form an opinion are continuous flow settlement with chemicals, primary ærobic filtration, and septic tank treatment. As regards the first mentioned, apart from the cost of the chemicals and the difficulties incidental to sludge disposal, I certainly think it has advantages over the other two methods.

With reference to primary ærobic filtration, the advantage of such treatment is the freedom from nuisance attending the further disposal of the effluent, but as it is frequently impossible to provide the necessary increased fall, to avoid pumping the sewage the adoption of septic tank treatment is usually indicated.

Contact Beds.

My experience of the working of contact beds led me, eight years ago, to discard that method of treatment as being far inferior to treatment by continuous percolating filters constructed of fine particles. In my opinion, to obtain anything approaching the standard of effluent by contact as can be obtained by filtration, double contact, after septic tank treatment, is essential, and to arrive at a corresponding result, something approaching twice the total cubic capacity of the beds is necessary in the former case as compared with the latter. Moreover, the tendency to clogging in the case of contact beds is greater than in the case of filters. The former, therefore, have to be rested more frequently and for longer periods, and periodically it becomes necessary to empty the beds for cleansing purposes—a necessity which with legitimate working, has never arisen in my experience in the case of filters in which the filtering medium is satisfactory and of fine grade. Apart also from the chemical quality of the effluents, I invariably find that a contact effluent is dirtier in appearance than one from a fine-grain filter.

Some engineers recommend single contact after septic tank treatment, in cases where suitable land is available —a plan which, I think, has nothing to recommend it. In fact, if land filtration is to be the method of effecting the final changes, and the land is suitable, there is no need for further preliminary treatment beyond that of chemical precipitation, or septic tank treatment, and the introduction of single contact as an intermediary process is a waste of money. On the other hand, if suitable land of sufficient area is not obtainable, full bacterial treatment should be provided, although there may be cases in which land, while not sufficient for dealing with the entire sewage flow, may prove useful if held in reserve for storm sewage or made use of for treating a portion of the dry weather flow.

Continuous or Percolating Filters.

Question 121. *What do you find are the best filtering materials, and what size should the material be?*

In my opinion any hard non-friable material of irregular shape and not too smooth a surface, and one which is not liable to disintegrate is satisfactory as a filtering medium. Among such may be mentioned gravel, shingle, granite, blue bricks, saggers (a hard-baked clay, the discarded broken utensils in which potters' ware is packed for firing), clinker, coke, coal, &c. Ashes, on the other hand, are not satisfactory, owing to their friable nature. In Staffordshire a trial is now being made of selected furnace slag, such pieces as are porous or honeycombed being rejected. I am not yet in a position to say whether this material will prove permanently satisfactory and at present I should hesitate to advocate its use in view of possible chemical disintegration, especially if small-sized particles are used.

As regards the size of the filter particles, I am most decidedly of opinion that the smaller the grade compatible with aeration of the filter the better. In my experience the most effective size is $\frac{1}{8}$in. to $\frac{1}{4}$in., but, on the ground of economy, I advocate sizes of from $\frac{1}{4}$in. to $\frac{1}{2}$in. for the body of the filter, the top layer to a depth of from 9 in. to 12 in. being formed of the smaller grade particles. In the case of filters constructed of such sized particles, washed free from dust, and given a moderately clarified tank effluent, properly distributed, I have never found any clogging take place which could not be remedied by surface forking and a few days' rest, and I have instances of such filters having been worked continously for seven years and are still working with excellent results without having been disturbed. (See Table IV.) On the other hand, I know of large-particle filters, worked on identical lines, which have become clogged in a few months.

Question 122. *What depth should a percolating bed be to obtain a good effluent? If this varies with the quality of the liquid going on, or with the size of the filtering material, please state how it varies, what depths you require for different liquids, and how you would distinguish one liquid from another, i.e., what analytical figures you would rely on, for this purpose?*

The efficient depth for a filter of such sized particles as I have approved is, in my opinion, 5ft. Such a filter, under ordinary circumstances, will produce an excellent effluent from sewage which has first undergone preliminary treatment, either in a primary filter of larger sized particles ($\frac{1}{2}$in. to 1in.), or by means of septic tank treatment or chemical precipitation. In the case of brewery sewage, however, or a sewage containing a large amount of tannery waste, I am not so confident that a filter of that depth would suffice, unless the rate of flow, and, consequently, the rate of travel through the filter is considerably reduced, or, as an alternative, double filtration is resorted to through, say, 4 ft. filters.

Question 123. *Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?*

Sewage need not necessarily be subjected to tank treatment, beyond that requisite for the separation of the detritus, before it is put on percolating filters. As a substitute for such tank treatment, the sewage, after treatment in detritus tanks, may be prepared for final filtration by being passed through a roughing or primary filter.

About five years ago I completed certain experiments on these lines at Burslem, in Staffordshire, where the sewage, after screening and subsidence of the detritus, is pumped to land. For the purpose of the experiment the rising main was tapped in order that the sewage might be delivered to the experimental plant, consisting of two percolating filters each having an area of 67 square feet, and a depth of 4ft. 6in., and so placed as to allow of the effluent from the one filter being passed through the other, the method of distribution being by notched fixed troughs, 9 in. wide, fixed 9 in. apart.

The filters were worked for twelve hours and rested for twelve hours, and the volume of sewage treated per superficial yard of filter daily was 190 gallons. The figures of analyses of the sewage and effluents after nine months' continuous working of the plant are set forth in Table IV.

I have no doubt that even a better result would have been obtained had the means of distribution of the sewage on the filters been more satisfactory.

I may mention that these filters were continued in operation for some two or three years longer with equally good results, and without any appearance of clogging, in fact, the particles in the interior of the filters, especially the second one, retained their clean light-coloured appearance throughout, notwithstanding the immense amount of suspended solids in the sewage as delivered to the filters. I estimate that in twelve months the first filter must have liquefied a bulk of wet sludge of about three times its available capacity.

Question 124. *Is the material better disposed in the form of two beds, to be fed in succession with the same liquid, or in one deep bed?*

In my opinion, if, owing to the special character of the sewage, it is found that a filter of much greater depth than five feet is required, it is better to provide two beds. This, of course, from the point of view of distribution especially, will be more costly than one filter equalling the two in depth, but the advantage, from an aeration point of view, would be considerable. At the same time, it is only in the case of exceptional sewages that double filtration after tank treatment may be required; under ordinary circumstances a fine-particle filter, five feet deep, gives excellent results with efficient distribution.

Question 125. *How should percolating filters be fed?*

The great object to be obtained is uniformity of distribution, the sewage being applied in as finely a divided state as is practicable.

Question 126. *Should the feed be intermittent or continuous?*

I think the feed should be continuous, that is without any rest periods, except periodically and at more or less long intervals, for the purpose of resting the filters, either

when they may require such rest or when, owing to small volume of flow, the full plant is not required.

Question 127. *What is the best form of distribution? What, in your opinion, are the conditions which have to be fulfilled by a perfect distributor, having regard not merely to the distribution of the liquid itself, but also to the purification of the liquid and the life of the bed?*

Undoubtedly the best form of distribution is by power-driven appliances, such as the Commission have seen at work at Hanley. By means of these all the important factors are under control, and the wind has no effect upon the rate of travel of the apparatus. Revolving distributors worked by a head of sewage are a great advance upon previous methods, such as troughs and intermittent automatic flushing on to the surface, the sewage being held back by a top layer of fine material. On the other hand, spraying the sewage by means of pipes and jets answers very well, as at Lichfield, where the outfall is in the open country, but if the works are in the neighbourhood of houses, even as far distant as a quarter to half a mile, nuisance is sometimes experienced from this method, especially in the summer, owing to the large area of sewage in fine division which is thus exposed to the air. Chesterfield sewage works is a case in point, where, on my suggestion, revolving distributors were substituted for sprays on this account. In my opinion the best of the non-power driven distributors is Fiddian's which the Commission saw at work at Walsall, but which has recently been improved by the addition of vanes to counteract the effect of wind pressure. I recently conducted a series of tests with this form of distributor in another district in Staffordshire, and found that the mean fluctuation over or under the mean delivery per yard of filter only amounted to 10 per cent.

In my opinion the chief objection to most automatic distributors is the necessity for discharging the sewage in bulk at interva's, which results in charging the filter, for the moment, with an enormously increased flow per yard, causing the sewage to pass more rapidly through the filter; this objection does not apply to the Fiddian distributor.

The following, in my opinion, are the conditions to be fulfilled in a perfect distributor:—

(*a*) Uriform and fine distribution without exposing a large surface of sewage in fine division to the air.

(*b*) The discharge of the sewage on to the filter in such a manner that the slowest rate of travel through the filter is achieved without reducing the volume passed through per day.

(*c*) The avoidance of any arrangement which may give rise to trouble from freezing.

Question 128. *Do you think it best to put on a filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?*

According to my experience, small-particle filters, with uniform distribution, may be worked at a certain rate for long periods without any clogging or deterioration in the results. In the case of 5ft. filters I have found that with ordinary sewage 200 gallons per square yard may be passed through continuously with excellent results, but if that rate is exceeded for any length of time the effluents deteriorate in quality until a point is reached when a few days' rest becomes essential. At the same time, periodically, and for a limited period, the rate of filtration may be considerably increased without much impairment in the results, the filters very soon recovering their former efficiency, without being rested, on resuming the regular rate of filtration. Notwithstanding this, however, in determining the area of filters to be provided, it is desirable to make a more liberal allowance than I have indicated, in order to permit of the occasional resting of the beds.

Question 129. *Is there any practical advantage in artificially heating the liquid which is being treated upon percolating filters?*

I have had no experience of the working of filters with artificially heated liquid, but judging from the published results in the case of artificially aerated filters with heated air, it does not appear that there is much to be gained by the adoption of such a plan.

Question 130. *Have you had any experience to show whether open sides are an advantage to a percolating filter?*

My experience does not show that there is any advantage in constructing filters with open sides.

Question 131. *Have you made any study of the conditions of aeration of percolating filters?*

I have not made any special study as to the conditions of aeration of percolating filters.

Question 132. *What do you consider is the most convenient superficial area for a percolating filter?*

The convenient area for a percolating filter is governed to a large extent, by the size of the works and the method of distribution adopted.

In the case of small works, the necessity for dividing the filter area to allow of interchange and resting may dictate smaller filters than otherwise would be provided if economy alone were studied.

Again, in the case of automatic distributors, the workable area is limited by the mechanical difficulty of providing an apparatus which will work satisfactorily if the span exceeds a certain limit. Probably this limit is at present found to be from 130 to 150 feet, but at Chichester a revolving distributor (Mather & Platt's) serving a circular filter 200ft. in diameter has been in operation for some 18 months, and, except during periods of high wind, when its automatic working fails and electrical power driving has temporarily to be employed, the distribution is good, the mean fluctuation over or under the mean delivery per yard being under 10 per cent.

Question 133. *Do you think it desirable that the bottom of a percolating filter be raised from the ground?*

From practical experience, I have come to the conclusion that there is no advantage in having the bottom of the filter bed above ground; theoretically, possibly it might be expected to be otherwise.

Question 134. *Do percolating beds, in your experience, choke? If so, have you been able to measure the rate of choking, and how do you suggest that this choking can be removed, and at what cost?*

If percolating beds are constructed of fine-grain particles (not exceeding $\frac{1}{4}$in. to $\frac{1}{2}$in.) and are not habitually and for long periods overtaxed, in my experience, choking does not occur, except to an extent which occasional short rest and surface forking will remedy.

Questions 135 to 138. 135. *Of what nature are the suspended solids in the filter effluent? How much is organic matter, and are they putrescible apart from the liquid portion of the effluent?*

136. *To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a percolating filter is different from the organic matter of the suspended solids going to that filter?*

137. *Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter? and to what minimum figure do you think such settlement or other final treatment can be carried as a practical measure?*

138. *Do you find that the suspended solids in your filter effluent vary much in amount from time to time, and if so, can you explain the causes of such variation?*

In the case of modern works the filter effluents I have had to deal with have been free, or practically free, from suspended solids. In my experience it is only in the case of contact beds and filters formed of large particles that suspended solids are present in the effluents. (See Table IV.)

Question 139. *What is the cost of percolating bed installation per acre, and how much liquid can be treated per acre per 24 hours, at ordinary times and in storm times?*

The cost of percolating filters varies very much in accordance with circumstances; for example, the local facilities for obtaining suitable filtering material, whether the filter is entirely or partially above or below the surface, whether retaining walls or concrete linings are provided, or whether the filtering material is simply placed in an excavation in the ground with banked-up sides.

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The following are the particulars as to the construction and cost per acre in the case of three types of percolating filters, all of which, to my knowledge, have given, and are giving, excellent results:—

Construction.		Distribution.	Preliminary Treatment.	Inclusive cost per Acre.
Walls.	Filter Medium.			
1.—Earthen embankments, lined with cement concrete, 5ft. 3in. deep.	Broken shingle. Body ¼in. particles. Top layer ⅛in. particles.	Mather & Platt's Revolving Distributor. Automatic except during heavy winds when electric power is used	Chemical Precipitation	£4,285.
2.—Close brickwork above ground. Longitudinal, 4ft. 9in. deep.	Broken 'saggers.' ¼in. to ½in. particles.	Power driven by electric motor.	Septic Tank.	£5,500
3.—Entirely under ground, without any lining on sides or bottom. Longitudinal, 5ft. deep.	Coal. ¼in. to ½in. particles.	Spray distribution by pipes on surface of filter.	Chemical Precipitation	£4,508.

As regards No. 3, owing to the absence of any brickwork or concrete, the cost, without loss of efficiency, would have been considerably less had a less costly medium than coal been used.

Analytical figures showing the working of various plants are set forth in Table IV.

Question 140. *Have you made any experiments which throw light on the action of percolating filters, with regard to the oxidation of—*

(A) *the ammoniacal and organic matter in solution.*

(B) *the organic matter in suspension?*

I have not made any experiments bearing directly upon this question, but the following are what may be called the impressions I have formed from observing the practical working of filters and from the numerous analyses I have made of sewages and tank and filter effluents:—

(*a*) As regards the ammoniacal and organic matter in solution, if the filter is in a healthy active state and the sewage is of normal character, it would appear that a high standard of oxidation is effected in about seven minutes, the time which the liquid takes to pass through a fine grain 5ft. filter, if the delivery is at the rate of 200 gallons per twenty-four hours and the distribution is uniform over the whole area of the filter.

(*b*) As regards the organic matter in suspension, it appears in the case of such a filter to be entangled in the upper layers of the filtering material, where it is gradually liquefied and, passing downward, becomes oxidised with the organic matter previously in solution. The process of liquefaction in this case is, I suggest, probably largely effected by aerobic liquefying organisms.

In the case of large-particle filters and contact beds, a considerable proportion of the organic suspended solids is washed through with the effluent. This constitutes one of the objections to such filters and beds, but, in my opinion, the most serious objections are—first, the comparatively small area available for bacterial growth, and, secondly, the fact that organic solids are permitted to pass down into the deeper layers of the filter, where the purely oxidising process should, as far as possible be exclusively in operation.

Question 141. *Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter or that they are first absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one?*

I have no evidence which enables me to offer any decided opinion on this point apart from what I have stated in reply to the previous question.

Question 142. *Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter?*

When active nitrifying properties are once established in a percolating filter, I cannot say that I have observed any material change in the quality of the effluents in different seasons. I am satisfied, however, that a newly-constructed filter is longer in acquiring nitrifying properties in winter than in summer.

Question 143. *Have you found any trouble from vegetable growths in percolating filters? If so, have you been able to form any opinion as to the causes of these growths and as to the way in which the growths can be prevented?*

I have had no personal experience of the occurrence of vegetable growths in percolating filters.

Question 144. *Do you find any nuisance from the treatment of sewage on percolating filters? Have any complaints been made?*

Undoubtedly nuisance does arise sometimes from the treatment of sewage on percolating filters, and sewage containing brewery waste in considerable quantity is specially liable to cause such nuisance. I have also found that nuisance is likely to arise from unduly prolonging septic tank treatment.

As a rule the difficulty may be overcome by shortening the period of preliminary tank treatment as much as possible, and adopting a method of distribution on the filters which exposes as small a surface of tank effluent to the air as possible.

In the case of strong brewery sewage it is possible that the addition of a cheap antiseptic to the tank effluent before distribution might remedy the nuisance, but the quantity used must, of course, be carefully regulated so that when mixed with the sewage it is present in sufficient strength to act merely as a deodorizer, otherwise the vitality of the organisms in the filter might be impaired. I think it is likely that this expedient will be tried in a case in which I am at present interested, where brewery waste constitutes about two-thirds of the sewage flow, and the works are situated close to a residential locality. In this case the antiseptic to be tried will probably be "oxychloros," prepared on the spot from a solution of salt by electrolysis.

General Questions in regard to Filters (Including Contact Beds).

Question 145. *Would you kindly compare the cost (initial expenditure and annual cost of upkeep and working) and relative advantages of percolating filters and contact beds. Do you consider that one form is best for some kinds of sewage, and the other form for other kinds of sewage?*

As regards the comparative cost of percolating filters and contact beds, I should say that, both as regards initial expenditure and annual cost of upkeep and working, the latter are the more costly, for the following reasons:—

(1) To obtain anything approaching a corresponding result from contact beds as from small-particle filters, double contact, as compared with single filtration, is essential, and the total cubic contents of the contact beds should about equal twice that of the filters.

(2) The automatic gearing for filling and discharging contact beds, or, as an alternative, manual labour, probably equals the cost of distributors for filters.

(3) As in the case of percolating filters the sewage is not head up, the provision of walls or concrete linings is not

essential if the beds can be constructed below ground level; on the other hand, in the case of contact beds, the sewage being held up, walls or linings, together with concrete bottoms are essential in most cases and desirable in all. This, of course, from a structural point of view, adds greatly to the cost of contact beds compared with filters constructed entirely or partly below the surface.

(4) As contact beds are far more liable to clog than small-particle filters, the upkeep cost in that respect in the case of the former is greater than in the case of the latter.

I consider that small-particle filters are greatly superior to contact beds, no matter what kind of sewage has to be dealt with. I formed this opinion some eight or nine years ago, and subsequent experience has never caused me to modify it, in fact, I think the introduction of the contact method was an unfortunate step, because its apparent simplicity led to its very general adoption, and thus tended to delay progress in overcoming the initial difficulty associated with filtration, namely, providing for the uniform and fine distribution of the sewage on the filters.

In comparing contact beds with filtration, I wish it to be understood that the filters I have in my mind are those formed of small not large particles.

Question 146. *Do you find that the chance of nuisance is any greater with one form of filter than with another? Does the risk of nuisance depend on the kind of sewage which is being treated or on the nature of the preliminary treatment to which the sewage has been subjected? The question of nuisance is important, and I should be glad if you would state your views fully on these points.*

As regards nuisance, I do not think that with proper management the risk is greater with one method than with the other. When once the sewage penetrates the filter or contact bed the risk of nuisance, so far as that portion of the liquor is concerned, is at an end, supposing the beds are in a healthy state. The real trouble is associated with the delivery to the beds, and I do not think that any larger surface of sewage need be exposed to the air during that process in the one case than in the other.

The risk of nuisance is undoubtedly greater in the case of certain sewages than others. As regards ordinary domestic sewage, there need be no appreciable nuisance, even near to the works, but the case is very different with sewages containing a large amount of brewery and, possibly, tannery waste, as I have already indicated in my answer to Question 144, in which I also suggest possible remedies. The question of nuisance arising from the disposal of screenings, sludge, &c., is dealt with later.

Question 147. *Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of tank liquor or tank liquors, could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on contact beds? If so, would you kindly state the results, at the same time telling us in precise terms what was the composition of the tank liquor or tank liquors, and what you are considering to be a satisfactory effluent.*

According to my experience, a fine-particle percolating filter, five feet deep, is capable of producing, practically for an indefinite period, an effluent of great purity, at a rate of delivery of 200 gallons per superficial yard per 24 hours (120 gallons per cubic yard). As I have previously stated, to obtain the same result from contact beds double contact (after septic tank treatment) is essential, each bed having, approximately, the same cubic capacity as the filter. In other words, to obtain the same result by contact beds as by percolating filters, the cubic capacity of the former must be about twice that of the latter.

Question 148. *Could you express an opinion as to how the number of gallons would vary with variations in the strength of the tank liquor, and on what figure or figures you would rely for defining the "strength" of the tank liquor?*

So far as ordinary domestic sewage is concerned, I believe the strength of the tank liquor, as measured by the amount of unoxidised matter it contains, affects the question of the volume per yard a fine-grain filter is capable of purifying much less than is generally supposed, but I am not so confident that the same may be said regarding contact beds or large-particle filters. In my opinion, the working capacity per superficial yard of a fine grain filter depends upon the volume rather than the strength of the sewage, that being the factor which determines the degree of aeration of the filter.

Question 149. *Have you had any experience of storm water filters? If so, would you kindly give us the results of it.*

So far, I have had no experience of the working of storm water filters, although at the present time several large works are in course of construction in Staffordshire in which such filters are being provided. I cannot say that I am very confident as to their success, but as the capacities of the works in other respects are very liberal (being on the present Local Government Board basis) the probability is that we shall not be dependent upon the storm filters to any great extent. Theoretically, I think all we can expect storm filters to effect is an advancement of the stage of purification to an extent which will facilitate the further purification in the stream through mixing with the nitrified effluent from the filters proper.

Question 150. *Do you consider storm water filters lose any of their efficiency by being used intermittently at long intervals?*

In my experience, dry weather flow filters which have had a long rest, say two or three weeks, on being again brought into use yield effluents of a high degree of purity, the nitric nitrogen in the effluent being greatly increased, and in all probability the first effluents from a storm sewage filter after a period of rest would be of good quality in that respect, although, at the rate of delivery at present allowed in the case of such filters (500 gallons per superficial yard), the quality would rapidly deteriorate.

Sludge.

Question 151. *Have you any practical suggestions to make for disposing of sludges, i.e.:—*

(*a*) *Sewage screenings.*
(*b*) *Material from detritus tanks.*
(*c*) *Sludge from precipitation tanks*
(*d*) *Sludge from septic tanks.*
(*e*) *Sludge from settlement tanks.*

In the handling of sludge, nuisances no doubt are frequently experienced unless proper precautions are adopted, and the nuisance in certain cases is much greater than in others, for example, in the case of brewery sewage.

(*a*) (*b*) As regards sewage screenings and material from detritus tanks, frequent removal and disposal on land is a satisfactory method even if the area of land available is very small. A shallow trench should be dug, into which the refuse should be placed, and immediately covered over with soil. The same land may be used over and over again if it be suitable, and it usually is found to be so, as a few inches of top soil is all that is necessary.

(*c*) The only practicable method of disposing of sludge from precipitation tanks, unless the works are in a locality far removed from houses, is by sludge pressing; the pressed sludge to be removed at short intervals.

If land is available, and the outfall works are not in the immediate neighbourhood of houses, the sludge may be disposed of in the same way as is suggested in the case of (*a*) and (*b*).

(*d*) It is remarkable how free from smell septic tank sludge is, so much so that no nuisance will be experienced from its being spread on land even in close proximity to dwellings.

(*e*) The sludge from settlement tanks should be dealt with in the same manner as suggested in the case of that from precipitation tanks.

Question 152. *Do you find that some methods of disposing of sludge are more likely to cause nuisance than others?*

If sludge is discharged into lagoons, where it is left to consolidate by evaporation and drainage, a practice which was frequently adopted before sludge pressing was introduced, the nuisance arising from the practice is considerable.

Questions in regard to Effluents.

With one exception, all the questions under this heading were answered by me when I previously gave special evidence before the Commission. The following question, however, was not then dealt with specifically:—

Question 154. *Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?*

I am most decidedly of opinion that a contact bed effluent is inferior to that from a percolating filter formed of small particles. I am not so confident, however, that the difference is so pronounced if the comparison is made with an effluent from a filter formed of large sized particles.

Comparing the effluent from a contact bed with that from a small-particle percolating filter, say 5 ft. deep, but of the same cubic capacity as the contact bed the advantage, in my opinion, is immensely in favour o

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the filter; in fact, as I have already stated, to obtain anything like corresponding results from contact beds as from small-particle filters, the capacity of the former should about equal twice that of the latter.

By double contact after septic tank treatment, a non-putrescent effluent can undoubtedly be obtained, but its quality as judged by the reduction of the albuminoid ammonia and oxygen absorbed and the degree of nitrification, will not equal that from a similar tank effluent treated by single filtration through a fine-grain percolating bed, neither will it equal the latter in appearance, a contact effluent, in my experience, being invariably cloudy or foul looking, while a fine-grain filter effluent is clear, in fact, hardly distinguishable from drinking water.

In the case of a weak sewage, single contact after septic tank treatment may produce a non-putrescent effluent, as at Exeter, but this, in my experience, is exceptional.

Some years ago, in conjunction with four other experts, I had occasion to report upon the treatment of the sewage of two towns by septic tanks and single contact beds, and having made a series of analyses, we found that, while the results obtained in the one case were undoubtedly satisfactory, in the other case they were quite the contrary. In the former case, however, we found that the sewage was quite exceptional in character, for not only was it very weak, but it also contained nitrates, in some samples as much as 2 pts. per 100,000; on the other hand, the sewage in the latter case was of quite a different character, and the treatment proved to be most unsatisfactory.

MISCELLANEOUS QUESTIONS.

Most of the questions under this heading were dealt with in my previous evidence before the Commission.

Question 159. *What is your experience of the effect of storm water upon filters of various sorts?*

If the volume of sewage delivered to filters is greatly increased during the storm times, a rapid deterioration in the results obtained undoubtedly takes place, but by resting the filter and then resuming the ordinary flow the quality of the effluent rapidly improves, provided the suspended solids are held back from the interior of the bed by a fine top layer, say of $\frac{1}{8}$in. particles.

Such a filter may be overtaxed with impunity; on the other hand, if precautions are not taken to prevent the penetration of solids into the interior of the filter, great damage may result in the case of filters composed of large-size particles.

Question 160. *How far do you consider it advisable for a sewage installation to be worked automatically?*

In the case of small works, for economical reasons, automatic working, as far as practicable, is advantageous, but in the case of large works, where the men in charge must necessarily be always on the spot, it is not so essential.

In the case of filters, whether on a large or small scale, there is great need for an automatic distributor which will deliver the sewage uniformly, under all conditions of weather, without having to resort to mechanical power or the automatic discharge of the sewage in bulk at intervals.

Question 164. *If there are any further points on which you would wish to speak we should be glad to hear your views on them.*

I venture to make the following comments for the consideration of the Commission regarding the practice of the Local Government Board in sanctioning loans for sewage disposal works, with the view of indicating how urgently some authoritative statement is needed regarding the question of the artificial disposal of sewage:—

(1) In view of the fact that the Local Government Board—notwithstanding the opinion already expressed by the Commission to the effect that land treatment is not essential—still hesitates to sanction disposal works without land, a definite and authoritative pronouncement on the subject by the Commission is urgently called for.

Lately, the Local Government Board, in cases where they have given way in the land requirement, have by way of compensation, required the provision of twice the area of bacteria beds than would satisfy them if land was provided. This imposes a very costly, and, in my opinion, needless condition upon authorities.

(2) If the Commission should be of opinion that present experience of the working of artificial bacteria beds does not absolutely warrant the Local Government Board in relaxing their requirements, I would suggest that schemes might be sanctioned without land, and without any compensating increased area of beds on authorities giving an undertaking to extend the works within a specified period if they should be found to be inadequate.

Possibly, in some cases, owing to the special quality of the sewage, such extension might be found to be necessary, but in the case of ordinary domestic sewage I am satisfied that no extension would be called for.

If this plan was adopted by the Local Government Board, an independent expert, approved by the Board might be appointed to periodically inspect the works and conduct the necessary analyses during the probation period, the cost involved to be deferred by the local authority interested. In the case of those administrative countries, however, where expert advisers have been appointed by County Councils, their services would, no doubt, be placed at the disposal of the constituent authorities for this purpose without charge, as the proposed sewage disposal works would, in any case, be subject to inspection by the Officers of such County Councils.

(3) In view of the present great diversity of practice regarding the construction of bacteria beds, it is very desirable that an authoritative pronouncement should be made as soon as possible regarding the type of plant which will give the best results under different conditions.

The present practice of the Local Government Board is to require the same cubic capacity of beds to be provided, no matter whether the method of disposal proposed is by contact beds or percolating filters.

This, on the face of it, seems to be an extraordinary practice, for, considering the radical differences in the two methods, it is hardly conceivable that the results obtained from the two classes of beds having similar capacities should be identical.

(4) As regards the construction of the beds, no matter what sized particles are used, the cubic capacity required by the Local Government Board is the same.

Considering the fact that the successful working of the beds depends upon the vitality of organisms, which require for their life processes certain important essentials it is again hardly conceivable that the highest state of activity can be arrived at and maintained, no matter whether the organisms are housed in filters composed say of 3 in. particles or $\frac{1}{8}$ in. particles or any grade between these sizes.

County Council Offices,
Stafford,
2nd May, 1905.

GEO. REID.

TABLE I.

TABLE SHEWING THE SUSPENDED SOLIDS, &c., IN CERTAIN STREAMS IN STAFFORDSHIRE UNDER DIFFERENT CONDITIONS OF RAINFALL AND FLOW.

		DOVE NR. BURTON-ON-TRENT. (Pure stream draining large rural area and a few small towns.)			TRENT AT HANFORD. (Foul stream draining comparatively small area partly rural but very largely urban.)			TAME AT TAMWORTH. (Very foul stream draining small rural area and very large and populous urban areas.)		
		Rainfall day before.			Rainfall day before.			Rainfall day before.		
		Under $\frac{1}{10}$in.	$\frac{1}{10}$in. and under $\frac{1}{4}$in.	$\frac{1}{4}$in. and over.	Under $\frac{1}{10}$in.	$\frac{1}{10}$in. and under $\frac{1}{4}$in.	$\frac{1}{4}$in. and over.	Under $\frac{1}{10}$in.	$\frac{1}{10}$in. and under $\frac{1}{4}$in.	$\frac{1}{4}$in. and over.
No. of Records		37	8	7	33	11	8	33	7	7
Mean Rainfall.	Day before	0 01 in.	0·16 in.	0·39 in.	0·01	0·18	0·46	0 007	0 14	0·56
	Week before	0 63 in.	0·93 in.	0·88 in.	0·43	0·86	1·15	0·37	0 69	1·13
	Month before	2·90 in.	2 55 in.	2·58 in.	2·30	2·37	3 42	1·87	2·34	2·65
Parts per 100,000.	Suspended Solids	0 9	4 1	2·2	4·9	18·3	16·2	3 9	6·9	8·1
	Chlorine	2·1	2·1	2·0	5·1	7 1	4·9	11·4	10 9	10·7
	Albuminoid Ammonia	0·019	0·030	0·027	0·095	0 171	0 100	0·111	0 106	0·199
Flow in cubic feet per second		321	419	293	59	79	129	316	344	665

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TABLE II.

Table shewing Mean Figures of Analyses of Corresponding Samples before and after Subsidence.

		No. of Samples.	Mean flow in Cubic feet per Second, giving No. of Records in each case.	Parts per 100,000. Solids. In Solution.	In Suspension.	Total.	Free Ammonia.	Albuminoid Ammonia.	Remark
Stream A	Before Subsidence	4	32 Cubic feet	103·0	5·5	108·5	0·354	0·068	Stream D before receiving B and C.
	After „	4	314 Records	101 5	2·7	104·2	0·407	0·062	
Stream B	Before „	6	2·5 Cubic feet	88·3	40·3	128·6	0·629	0·299	Tributary of Stream D.
	After „	6	312 Records	87·5	7·6	95·1	0·625	0·120	
Stream C	Before „	6	8·6 Cubic feet	44·2	5 8	50·0	0·160	0·113	Tributary of Stream D.
	After „	6	170 Records	42·2	0·6	42·8	0·125	0·063	
Stream D	Before „	5	43 Cubic feet	9·6	9·4	101·0	0·490	0·118	Formed by the Union of A, B, and C.
	After „	5	314 Records	90·8	1·4	92 2	0·448	0·090	
Stream E	Before „	5	84 Cubic feet	90·8	26·4	117·2	0·977	0·369	Stream D lower down; the increased flow being practically entirely from partially treated and untreated sewage.
	After „	5	314 Records	89·0	4·8	93·8	1·062	0·110	

Note.—The Gaugings of Flow covered a period of Eight Weeks.

TABLE III.

The following are the mean figures of a number of analyses of typical chemical precipitation tank effluents in Staffordshire, the capacities of the tanks, population, and dry weather flow of sewage being given in each case :—

District.	Population, Census 1901.	Dry weather flow per 24 hours in gallons.	Capacity of Tanks in gallons.	Period of Quiescence.	Precipitants used.	No. of Records.	Parts per 100,000. Solids. In Solution.	In Suspension.	Total.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 4 hours at 80° F.
Hanley - - -	61599	3,000,000	1,500,000	12 hours	Sulphate of Iron and Lime	9	87·6	2·8	9 ·5	10·0	2·156	0·304	1·640
Lichfield - -	7902	350,000	340,000	23·3 „	Alumino-ferric and Lime.	10	62·5	3·6	66·1	7·6	2·036	0·348	1 559
Newcastle - -	19914	864,000	416,000	11·5 „	Chloride of Lime only.	4	86·7	6·0	92·6	12·5	1·978	0·591	3 071
Wednesbury -	26554	600,000	366,000	14·6 „	Alumino-ferric and Lime.	4	75·5	2·0	77·7	11·9	2·271	0·253	1·077
Wolverhampton	94187	3,000,000	1,546,900	12·3 „	Lime only.*	2	115·9	1·8	117·7	20·4	3·992	0·426	2 574

The Wolverhampton sewage contains iron from Galvanisers' acid waste.

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TABLE

PARTICULARS AS TO THE WORKING OF PERCOLATING FILTERS AND

DISTRICT.	Population, 1901 Census.	Nature of Sewage.	Nature of Works.	PARTICULARS OF FILTERS AND BEDS.				
				Material.	Depth.	Grade of Material forming Body.	Distribution.	Rate of Filtration and Rest Periods.
BROWNHILLS -	15252	Domestic	Septic Tank and Percolating Filters (single filtration).	Furnace Slag.	5ft. 3in.	Slag = 3 16th in. to 1-16th in.	Spray Feed by Ajustable Perforated Iron Pipes.	175 gallons per square yard per 24 hours (100 gallons per cubic yard). Work 8 hours, rest 16 hours.
				Coal - -	5ft. 3in.	Coal = ¼in.		
BURSLEM - -	38766	Largely Brewery	Primary and Secondary Filtration after subsidence of Detritus.	Broken Saggers.	4ft. 6in	First Filter = ½in.	Troughs -	190 gallons per square yard per 24 hours (126 gallons per cubic yard). Work 12 hours, rest 12 hours.
				Broken Saggers.	4ft. 6in.	Second ditto = 3-16th in.	Troughs -	
HANLEY - -	61599	Domestic	Septic Tank and Percolating Filters (single filtration).	Broken Saggers.	4ft. 6in.	½in. to ⅛in.	Mechanical Power-driven Apparatus.	200 gallons per square yard per 24 hours (133 gallons per cubic yard). Continuous Feeding.
LICHFIELD - -	7902	Very largely Brewery	Chemical Precipitation and Percolating Filters (single filtration)	Coal - -	5ft. 0in.	¼in. to ⅛in.	Spray Feed by Adjustable Perforated Iron Pipes.	110 gallons per square yard per 24 hours (66 gallons per cubic yard). Work 8 hours, rest 16 hours.
PELSALL - -	3626	Domestic	Septic Tank and Percolating Filters (single filtration).	Coal - -	4ft. 0in	¼in. to ⅛in.	Spray Feed by Adjustable Perforated Iron Pipes.	No regular volume of flow or period of working.
SILVERDALE -	7820	Domestic	Subsidence and Double Contact.	First Contact = Broken Bricks.	3ft. 0in.	First Contact = 2½in.	Hand fed -	First Contact = 112 gallons per cubic yard per 24 hours. Second Contact ditto ditto. Filled and discharged twice in 24 hours.
				Second Contact = Coke breeze.	3ft. 0in.	Second Contact = ½in. to ¼in.	Hand fed -	
TIPTON - -	30543	Domestic	Chemical Precipitation and Percolating Filters (single filtration)	Lowcock Filter = Gravel and Sand.	3ft. 9in.	Lowcock = Pea Gravel.	Troughs -	Lowcock Filter = 100 gallons per square yard per 24 hours (80 gallons per cubic yard). Work 12 hours, rest 12 hours.
				Garfield Filter = Coal.	3ft. 9in.	Garfield = ¼in. to ⅛in.	Troughs	Garfield Filter = 200 gallons per square yard per 24 hours (160 gallons per cubic yard). Work 12 hours, rest 12 hours.
FIVIDALE -	2500	Domestic	Septic Tank and Double Contact.	Furnace Slag.	3ft. 0in.	First Contact = 2½in. to ¼in. Second Contact = ½in. to ⅛in.	Contact Beds = hand fed on to Troughs.	First Contact = 168 gallons per cubic yard per 24 hours. Second Contact ditto. Filled and discharged 3 times in 24 hours.
DITTO - - -		Domestic	Septic Tank and Percolating Filters (single filtration).	Furnace Slag.	6ft. 0in.	Filter = 1in. to ½in.	Filter = Fiddian's Automatic Distributor.	Filter = 223 gallons per square yard per 24 hours (111 gallons per cubic yard). Work 14 hours, rest 10 hours.
WOLVERHAMPTON.	94187	Largely Galvanizers' Waste.	Chemical Precipitation and Percolating Filters (single filtration)	Coal - -	5ft. 0in.	¼in. to ⅛in.	Spray Feed by Adjustable Perforated Iron Pipes.	200 gallons per square yard per 24 hours (120 gallons per cubic yard).

V.

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CONTACT BEDS IN STAFFORDSHIRE, WITH ANALYTICAL RESULTS.

Time covered by Records.	Sample.	No. of Samples.	Parts per 100,000. Solids. In Solution.	In Suspension.	Total.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 4 hours at 80° F.	Nitric Nitrogen.	REMARKS.
2 years	Septic Tank -	1	68·8	8·0	76·8	11·0	2·040	0·330	2·300	Nil	The night flow of sewage is disposed of on land, also the storm sewage, *i.e.*, any flow in excess of the dry weather flow.
	Slag Filter -	3	92·7	0·8	93·5	6·3	0·224	0·185	0·981	1·57	
	Coal Filter -	2	113·5	0·3	113·8	7·2	0·187	0·116	0 560	1·64	
6 years	Sewage - -	9	99·0	32·0	131·0	11·0	3·335	1·132	4·288	Nil	These filters are experimental. The trough distributors work very imperfectly. Had the distribution been more uniform, the results no doubt would even have been better. The filters are still working regularly with good results, but the figures of analyses are for the earlier periods of the working.
	First Filter -	15	91·1	8·7	99·8	10·9	1·851	0·506	1·746	0·36	
	Second Filter -	15	93·9	1·1	95·0	10·7	0·549	0·156	0·698	2·01	
2 years	Sewage - -	8	125·4	62·9	188·3	8·9	2·109	0·765	3·854	0·03	These filters were experimental but of large area, and the distribution was very perfect.
	Septic Tank -	7	105·3	4·4	109·7	8·7	1·820	0·270	1·725	0·09	
	Filter - -	13	112·3	0·6	112·9	8·3	0·069	0·029	0·260	1·66	
6 years	Sewage - -	4	75·2	75·0	125·0	10 8	3·567	1·401	5·133	Nil	On the whole the distribution is moderately good. No trouble has been experienced from clogging until the past few months, when the filters were overworked. Two new filters on the same lines are now being constructed. The material in the body of the filters is still clean and sharp.
	Tank - -	10	62·5	3·6	66·1	6·6	2·036	0·312	1·559	0·01	
	Filter - -	24	79·2	1·1	80·3	8·4	0·408	0·054	0·342	1·42	
5 years	Sewage - -	4	81·2	44·4	125·6	8·1	1·990	1·213	4·629	Nil	These filters were not in constant use, the tank effluent being occasionally discharged on to land.
	Septic Tank -	5	67·2	5·3	72·5	7·0	1·045	0·250	1·537	Nil	
	Filter - -	5	75·6	1·1	76·7	8·2	0·322	0·051	0·335	1·19	
6 years	Subsidence Tank	8	83·6	16·5	100·1	7·3	2·892	0·496	2·315	0·19	These beds are experimental, and difficulty has been experienced from the clogging of the first contact bed.
	First Contact -	12	81·3	5·9	87·2	7·2	1·803	0·266	1·298	0·05	
	Second Contact	18	80·3	2·0	82·3	7·1	0·761	0·104	0·463	1·02	
2 years	Tank - -	13	82·7	1·6	84·3	10·2	1·250	0·230	0·770	Nil	These filters were experimental.
	Lowcock Filter -	8	80·7	1·4	82·1	10·0	0·270	0·050	0·220	0·74	
1½ years	Garfield Filter -	8	91·4	0·3	91·7	10·6	0·190	0·040	0·200	0·81	
Contact Beds = 4 years.	Sewage - -	1	132·5	16·3	148·8	13·8	1·233	0·421	1·800	0·08	The filter, but not the contact beds, was experimental.
	Septic Tank -	5	113·7	7·9	121·6	13·6	3·272	0·430	2·204	Nil	
	Second Contact -	11	115·1	3·0	118·2	11·9	0·654	0·100	0 361	0·55	
Filter = 2¾ years	Filter - -	5	133·4	0·8	134·2	13·2	0·100	0·055	0·368	2·28	
3 years	Sewage - -	1	152·0	69·2	221·2	31·3	9·580	3·530	—	Nil	This filter was experimental.
	Tank - -	2	139·5	2·2	141·7	26·1	5·161	0·505	3·263	0·33	
	Filter - -	11	159·5	1·1	160·6	25·3	1·173	0·073	0·351	1·88	

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24433. From your answer to Question 19 you appear to be of opinion that a local authority ought to possess some power with regard to the admission of trade effluents into the sewers. Now, how do you propose, if any dispute might arise between any local authority and a manufacturer it should be settled?—Well, if the suggestion of the Commission with regard to a central authority was carried out, I think that would be a very good authority to settle such a dispute. I do not mean a local central authority but a central board for the whole country.

24434. Yes, and may we take it that you agree with our recommendation?—I agree with the recommendation as regards the central board, but I do not agree with the recommendation with regard to cutting the country up into areas and appointing rivers boards systematically. I think in certain cases this ought to be done, but in other cases, where a large amount of work has been done, and it really now almost approaches completion, by the authorities which now exist, I think it would be a very great hardship to those authorities and their officers that the work should be taken from them. I think that the decision with regard to the need for the formation of rivers boards might rest with the central authority also.

24435. The central local authority?—The central administrative authority, I beg your pardon. For instance, in Staffordshire the expenditure that we have incurred in sewage disposal alone—that the authorities have incurred through the action of the county council—approaches £2,000,000 already, and there is a large expenditure still to be made and in process of being made.

24436. Then we may take it generally you agree with the spirit of our recommendation, only you think it is not necessary to have rivers boards everywhere?—Quite so.

24437. Because there are already in existence powers with adequate control?—Quite so; but I should give the power to the central body of compulsorily appointing rivers boards if they thought fit.

24438. And you quite agree with us as to the appointment of a central body?—Certainly.

24439. Would you look at that question included in list we submitted to you, as to the best way of dealing with sewage in storm times? You have not dealt with it in this evidence you have handed in. But if you had any views to lay before us as to the treatment of storm water generally it would be interesting to have them?—I really dealt with that matter in my previous evidence, I thought—the question of storm water and its admission into streams.

24440. In fact you consider that you have had your say, so to speak, in regard to that?—I think so; that was one of the special points that I was asked to give evidence upon on the previous occasion, and I omitted it on the present occasion as I had given evidence on it previously. I suggested that the present six times the dry weather flow required by the Local Government Board was reasonable. I gave statistics in the shape of figures as to the effect of storm waters on streams. I also suggested that central authorities such as county councils should be empowered to abolish weirs as bearing upon the question of storm overflows especially.

24441. (*Colonel Harding.*) You mean disused weirs?—Not necessarily disused weirs. We have in one or two instances pressed the local authorities in Staffordshire and they have taken steps to abolish them, by purchase when necessary. Where the streams are stagnant, weirs cause a very great nuisance indeed from the deposit of sludge above.

24442. (*Chairman.*) On question 54 have you any experience as to brewery waste?—I have.

24443. And can you tell us what precipitation is the best to use for that?—That is granting a precipitant is essential. In Lichfield, for example, we get very good results from lime and alumino ferric. If you refer to the last table you will find the results of the Lichfield works extending over a period of four of five years. It is fourth on the table. That is a very strong brewery sewage.

24444. Is the treatment at Lichfield satisfactory; I mean does it avoid a nuisance?—If Lichfield did not happen to be situated in the open country there would be nuisance from the distribution of the sewage on the filters, because it is distributed by sprays, but where the works are situated it does not matter. I have another instance in Staffordshire where it has given rise to very great nuisance, namely, Stone, where the brewery waste constitutes about two-thirds the volume of the sewage; and there is a proposal now under consideration for dealing with the septic tank effluent by means of an antiseptic before distributing it on to the filter, adding it in sufficient quantity to deodorise, but not of course to destroy the organisms.

24445. That is a proposal that has still got to be tried, I suppose?—Yes, I do not think there is much doubt about it being successful, because if the septic tank is covered and ventilated, and the gases are burned, which is intended, then I think that the margin between an antiseptic strong enough to destroy organisms, and an antiseptic strong enough only to deodorise is so very great that it might very readily be used by means of an automatic arrangement so as to deodorise sufficiently without going any further.

24446. On Question 74 can you give us any details about this tank that you have known to be in continuous use for three years without showing any need of renewal. I mean can you tell us where the place was and at what rate the tank was worked?—That was at Birmingham.

24447. And what was the nature of the sewage?—The nature of the sewage was domestic sewage with a certain amount, but not very much in proportion, of acid waste.

24448. And at what rate was the tank worked?—I think at that time the period of septic action was about fourteen hours, including the calculated period of the sewage in the sewers

24449. And there the sludge was almost entirely consumed?—Yes, it was.

24450. During the whole period of three years?—Yes, but large detritus tanks are in use there, and that, of course, is very important; I think the detritus tanks should be sufficiently large to save the septic tanks getting filled with solids. Mr. Watson, I believe, is giving evidence; he will be able to support that if he has not mentioned it already.

24451. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working; that is as the time approaches for removing the sludge from the filter?—I cannot say I have noticed that. With the exception of one case which was an experimental case, and was badly managed, I have never had any material trouble from any solids coming away from the septic tanks; I think this entirely depends upon the capacity of the detritus tanks.

24452. Question 86; is your answer founded on your own experience?—That is so; there are certain examples given in the general table. There is a special table dealing with chemically precipitated effluents—Table III. You will see the solids given in suspension there.

24453. As to your views about the value of single contact, you would not deny that single contact had a value I suppose?—It has a value, yes; it is a stage in the treatment, certainly.

24454. And in a case like Exeter which you say is exceptional, it answers all purposes, does it not?—Oh certainly, at Exeter; it did at the time that I was there. The Exeter sewage is most exceptional; it contains a remarkable amount of nitrates, and is very weak—the weakest I have ever had experience of.

24455. Then on the question of open sides to a filter you say, "My experience does not show that there is any advantage in constructing filters with open sides;" are you able to express that opinion with confidence; I mean to say is your experience in the matter large?—I have seen various works with filters with open sides, and I have never seen any advantage in the open sides at all; we get better results, I think, than most people, from small grain filters with closed sides; but in the case of small grain filters, open sides, of course, would not have the same application as in the case of large particle filters, because the air would not penetrate through from one side to the other. I have noticed a great nuisance

from flies in the case of open sided filters; an enormous number of flies come away in the effluent and you see them crawling about in the open sides of the filter; we do not get that nuisance in the case of closed filters.

24456. Then Question 164, you appear to think that the requirements of the Local Government Board where they dispense with land treatment are needlessly harsh?—I think so, distinctly.

24457. But where no land treatment is provided there must surely be some substitute for it?—I maintain that the capacity of filters usually required is sufficient to produce, if properly constructed, a high class effluent; you will not improve that effluent by placing it on land; you will rather deprive it of its vitality; it is not desirable to put it on land afterwards, I think; and I think that the area of filters necessary ought to be provided irrespective of land treatment; you ought either to have the one or the other; if you have biological treatment in filters well and good, that is if you have not sufficient and suitable land; but if you have sufficient and suitable land, then have land treatment; but I think it is a waste of money and a mistake to employ both biological treatment and and treatment.

24458. Oh, I see?—That is my position.

24459. Then if you had not sufficient land to make the one treatment for the whole of the sewage you would say do not use land at all? No, that is not my view. If some land is available, and is suitable, by all means use it, as far as it will go, for land treatment only, that is after preliminary tank treatment, and make use of filters without land for dealing with the flow beyond what the land can purify. I consider it a waste of land and a waste of filters to employ duplicate treatment.

24460. You would object really to mixing up artificial and land treatment?—For this reason, first because it is unnecessary and very expensive; and secondly, because I think that in most cases the effluent deteriorates in consequence. My point really is this that you can do it by the one process or by the other, and there is no need for or advantage in employing the two in duplicate.

24461. Then my last question is this: you criticise the practice of the Local Government Board in requiring the same cubic capacity of beds to be provided, whether the method of disposal is by contact beds or by percolating filters. Well, we have been told by some witnesses that the purifying effect per cubic yard is approximately the same whether it is a contact bed or whether it is a percolating filter for the sewage, but your experience is quite opposite to that?—Oh, most distinctly, that is so. Supposing you take a cubic yard and a half arranged as a contact bed, four feet six inches deep, and a corresponding cubic yard and a half arranged as a filter, then I say that the contact bed effluent would not approach the filter effluent in quality—the single contact.

24462. Now, have you experience in several places to bear out that opinion of yours?—As far as I am personally concerned—my own work is concerned—I have only the experience of one place; but I have observed other places. We have other works in Staffordshire, and I get effluents periodically from them, and I have, I may say, analysed single contact and double contact effluents, and my experience is that the single contact is invariably inferior, and very much inferior, to the filter effluent, although the double contact effluent certainly does approach the filter effluent; but in my opinion you require very nearly twice the capacity in the one case that you do in the other.

24463. I mean, you are not going by experience in one place only?—Oh, no, I am going by experience in several places, but not my own actual work; except in one place I discarded contact years ago in consequence of work I conducted at Tipton with filters and contact beds treating the same sewage. I must say that I began the experiment with the belief that the result would be what it turned out to be, but I have never had occasion in my subsequent experience of other works to alter that opinion.

24464. (*Colonel Harding.*) The special feature of the interesting evidence that you have brought before us, Dr. Reid, seems to me to be the fact that your experience in the Staffordshire district leads you to believe that septic tank effluent may be brought out, with so little as from five to eight parts per 100,000 of suspended matter?—Yes, with a proper detritus tank.

24465. And filtering an effluent so free from suspended matter you find that very fine material may safely be used?—I not only say that, but I think that even if the effluent contained much more suspended matter it would still be advisable to use fine material.

24466. Well, first in regard to the septic tanks: the evidence which has been brought before us is that as a rule in almost every case the amount of suspended matter in the septic tank effluents is considerably larger than you tell us is obtainable in the Staffordshire district; and one is anxious, therefore, to ascertain from you how far there are special conditions in connection with the Staffordshire sewages, or in connection with the construction, the working of septic tanks in Staffordshire to bring about these very exceptional results; you said just now that it was necessary that there should be preliminary detritus tanks?—Certainly.

24467. And I think you have quoted in one of your answers to Lord Iddesleigh's questions the septic tanks at Birmingham?—Yes.

24468. As showing that there was very little accumulation of sludge in the septic tanks there?—Yes, that is so.

24469. But I do not know whether you are aware of it, that in these septic tanks at Birmingham, in the period to which you refer, only about four parts or perhaps five parts per 100,000 of suspended matter were left in the tanks at all?—I do not understand what you mean by five parts.

24470. May I explain it in this way: quoting from Mr. Watson's own figures of Birmingham he says that at one period the effluent passing away from the roughing tanks, which are detritus tanks, only contained twenty-nine parts per 100,000 of suspended matter; the Birmingham sewage contains about sixty parts?—The roughing tanks would be the detritus tanks in this case.

24471. Yes, what we call the detritus tanks; so that of the sixty parts originally in the Birmingham sewage, thirty-one parts were left in the detritus tanks?—Quite so, the detritus tanks at Birmingham are very large.

24472. And only twenty-nine parts went forward to the septic tanks?—Yes.

24473. At the same period he says that the effluent passing away from the septic tanks contained twenty-five parts; and, therefore, there could only have been left in the septic tank the difference between twenty-five and twenty-nine, namely, four parts?—I see what you mean, yes.

24474. And, therefore, one would not be at all surprised that there was accumulation at an exceptionally slow rate seeing that so little was left behind?—Yes, they had been working three years at the time I am speaking of.

24475. That is one of the periods to which Mr. Watson refers in another case; he says he was able to bring about more effective sedimentation in the detritus tanks; and that in the second period only seventeen parts passed away in the effluent from the detritus tanks?—Yes.

24476. When that was the condition of things the suspended matter in the septic tank effluent was reduced to thirteen parts?—Yes.

24477. So that even then only four parts were left behind?—Twenty-four parts were removed, yes.

24478. I want to point out to you if what you have in view in giving us these figures is that there should be first of all natural sedimentation followed by septic tank action, quite on a minor scale; then one begins to understand how it is possible to reduce the suspended matter so far, but in the septic tank action, particulars of which have been given to us hitherto, as a rule almost everything goes into the septic tank; a great deal of matter is left in the septic tank?—Yes, naturally.

24479. In the Birmingham case which you quote, very little is left in the septic tank; now, I may take it that, speaking generally, that is the method of working in the district which you are speaking of?—No, in most of my districts the detritus tanks, although large, are not so large as at Birmingham, but relatively speaking, the septic tanks are much larger.

24480. Namely, that first of all, there is large sedimentation in so-called detritus tanks followed by much slighter

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sedimentation in septic tanks?—Followed by septic tank treatment for a longer period than is adopted in Birmingham. I think at one time in Birmingham the period in the septic tank was only about eight hours.

24481. Yes?—Well, I do not think that is sufficient.

24482. But the special point which I want to get at in explanation of the interesting data that you give us, is really to what extent the bulk of the suspended matter is in your district withdrawn from sewage before it passes to the septic tanks?—Oh very largely, very largely. I am not sure whether I give that or not.

24483. Where have you an instance—at Hanley, for instance, in your Table IV., I find there are sixty-two parts in the sewage?—Yes.

24484. And in the septic tank effluent there are only 4·4 parts?—Yes.

24485. A very small quantity indeed?—Yes.

24486. Now, between the arrival of the sewage at the works and its going into the septic tank what amount of sedimentation has there been in the detritus tank?—Oh, considerable sedimentation, the detritus tank had to be emptied twice a week.

24487. Have you any figures?—No, I have not.

24488. Do you happen to know how far the bulk of the suspended matter is left in the detritus tanks?—No, I have not analysed the effluent from the detritus tank going into the septic tank; I have only analysed the sewage and the effluent from the septic tank, so I cannot say to what extent the solids remain in the detritus tanks.

24489. Should you think the conditions were parallel to what I was giving you at Birmingham?—Oh, yes, except that the period of septic tank treatment is very much longer, namely, twenty-four hours at Hanley.

24490. In regard to the quantity of suspended matter going into the septic tank, do you think the conditions are the same as at Birmingham?—I do not think they are so favourable as at Birmingham, because the detritus tanks there are very much larger in proportion than at Hanley.

24491. Then we are to take it that when you speak about getting a septic tank effluent with so small a quantity of suspended matter in it, it is an effluent which has first of all been submitted to a process of natural sedimentation followed by septic tank treatment in which comparatively little matter is deposited at all?—At any rate comparatively little matter remains after a period of working, whether it is deposited and afterwards liquified and passes away or not I am not prepared to say.

24492. Can you really express an opinion as to the amount of digestion which takes place in the septic tank unless you have gone into the matter to the extent of what goes in and what comes out?—No, I say I cannot say whether what remains there is what comes in in the first instance or whether more goes in in the first instance and is digested while there.

24493. You are unable to express any opinion as to the amount of digestion in the septic tank?—Quite so; I have not done nearly so much work in that direction as I should like to.

24494. Clearly, then the explanation of there being in your experience so little accumulation in the septic tanks is that really very little is taken to the septic tank?—Well, it is either very little is taken to it, or if it is taken to it it is digested in it; that I am not at present prepared to answer; it would require to be gone into very carefully.

24495. It would be very interesting to us if you were able to put before us figures showing to what extent the suspended matter in the sewages in your district are first of all settled naturally, and to what extent they are septically treated?—Well, I shall hope to do that.

24496. It is a vital point, because in all the evidence that has come to us from other districts, in important places such as Manchester, Leeds, and many other places, where the septic action is the main action, the deposit in the septic tank is practically the deposit of all the suspended matter in the sewage, except what goes through with the effluent; in those cases it is found that, after a comparatively limited period, say two years, the tank reaches such a condition of accumulation that it is absolutely necessary to stop the work and empty the sludge out?—That is without the detritus treatment.

24497. Yes?—Oh, of course.

24498. Then the explanation of the peculiar results, from your district is that before the septic tank, there is very considerable natural sedimentation?—Oh, yes, certainly, if you like I will endeavour to get some information on that specific point, if the Commission would like it, at certain works to show exactly the sewage that goes into the detritus tank, the sewage that comes from the detritus tank, and the effluent which comes from the septic tanks

24499. That seems to us quite necessary in order to be able to judge of the value of the antecedent sedimentation?—Yes, it is very desirable; as I say, I should like very much to do it; most of my work hitherto has been directed to the main result—I had not time or opportunity to go sufficiently fully into all points of interest.

24500. We quite understand you are supervising the effluents, but you are not managing the sewage works; that is left to somebody else?—Quite so.

24501. Have you noticed in the septic tank, worked the way in which you say, the presence of considerable scums?—Well, sometimes considerable scums, sometimes very thick indeed and solid, but not by any means always.

24502. The scum is sometimes there, sometimes not at all?—It really seems to be a matter of wind; when the scum begins to form and gets anything like solid then the wind does not interfere with it.

24503. It has been suggested to us that when heavy rain comes it causes the scum to sink and then to bread up?—Yes.

24504. Have you noticed in connection with these septic tanks any great variation in the amount of suspended matter coming away?—I have not studied my records with that object in view, but there is undoubtedly great variation; I might look through my records and answer that question.

24505. All these authorities that you are speaking of, so far as you know, have not taken constant analyses in order to see the variation in the suspended matter coming out?—They do not make any analyses as a rule, that is mostly done by the county council only I regret to say.

24506. You probably are aware that at all events in other places where analyses have been taken there is considerable variation in the amount of the suspended matter coming away?—Yes, I can quite understand that.

24507. One of the reasons accounting for that variation is this question of scums. It is pointed out that in times of heavy rain the scum is forced down lower into the water, the gas supporting it is disturbed, and a great quantity of the matter held up then falls down, and passing in front of the pipe carrying away the effluent leads in that way to rushes of suspended matter?—Yes.

24508. My object in asking you these questions is to ascertain how far in your district, as elsewhere, at times considerably more than the very small quantities which you give us in these analyses come away with the septic effluent; at Hanley, for instance, you put down as coming away with the septic effluent so little as four parts?—Yes.

24509. But you probably think there are times when much more than that comes out?—If you like I will give you the actual figures of the analyses I have made with regard to Hanley; the mean figures only are given in the tables presented.

24510. Can you tell us within what limits they vary?—I am afraid I cannot without referring to my books of records.

24511. Is this the mean upon a large number?—No, only upon seven in this particular instance.

24512. Seven?—Seven separate septic tanks.

24513. Taken at the same period?—On different occasions.

24514. But at what age of the septic tank?—Well, I began about two months after they were first started, and the experiment, I think, was completed as far as these figures are concerned within about eighteen months.

24515. Then some of them would be experiments taken after the tank had been working about two years?—Yes.

24516. And do you find as a tank gets older, and as the accumulations such as they are increase, you get more suspended matter in the effluents ?—That I cannot say. Mr. Watson will be able to give you evidence upon that point, because he has had repeated samples taken of tank effluent during years of use without emptying.

24517. We have had a great deal of evidence from various places upon this point where constant analyses have been taken, and all that evidence goes to show that the amount of suspended matter coming away with the septic tank effluent steadily increases as the accumulations rise in the tank, and the capacity of the tank is diminished ?—Yes.

24518. And increases to a point when it is no longer economical to work the tank; it is better to stop and empty out the sludge ?—Yes, and I should say in these cases that the detritus tank accommodation, if it exists, is very much too small.

24519. In many cases it does not exist at all ?—In which case I do not see by what process anything else could happen if you turned the road detritus into a septic tank you must necessarily diminish its capacity very rapidly.

24520. You know at times the suspended matter in the septic tank effluent rises considerably ?—Beyond the 4·4; of course, that is a mean in that case.

24521. In other cases I see you have given us the matter going on to the filters as being 8, and you say in your answer that from 5 to 8 parts is the figure that it might be reduced to ?—Which should be aimed at.

24522. 5 to 8 parts ?—5 to 8 parts, yes.

24523. In your filters you look with approval upon an effluent which is very clear and contains exceedingly little suspended matter ?—Yes.

24524. And I think you say that in this district excellent results have been obtained, in which, if I may take Hanley as an instance, only 0·6 of a part of suspended matter has appeared in the effluent ?—Yes.

24525. In other cases, I find, for instance at Pelsall, that it is 1 part ?—Yes.

24526. Now, if 8 parts go on to the filter, and only 1 part comes away, what becomes of the other 7 parts ?—Well, I believe that they are liquified in the filter. With small grain filters all the solids are held back on the top; they do not go down into the interior of the filter at all. And I believe that liquifaction takes place on the top; it is constantly going on, and the solids do not really get into the interior of the filter at all. That is one reason why I believe it is very much better to have small particles on the top of the filters. On digging into these filters after they have been in use for two or three years, one finds that the solids are all really within the first 9 or 12 inches. I opened one of the filters at Lichfield the other day, and the filtering particles were quite foul down to about 9 or 12 inches; and afterwards right down to the bottom the particles were as clear as the day when they were put in. The same applies in the case of Burslem. There the filter particles are light coloured (Saggers); so one can judge very well as to their condition. Here crude sewage, after subsidence in a detritus tank only, is discharged on to the filters. The plant (double filtration) has been working for four or five years and the solids in the effluent are 1·1, while the solids in the sewage are 32·0; that is to say, after settlement. All those solids are digested in the filters. These filters are still giving good results and beyond surface raking and forking, nothing has been done to them during the whole period.,

24527. That is an exceedingly important point you have raised. Referring to your previous answers, you say that the suspended solids are held back by the top layer of the filter where they are digested; and in another passage you say they are entangled in the upper layers of the filtering material where the suspended matter is gradually liquefied ?—Yes.

24528. And you now name to us an instance where 32 parts go upon double filters and only one part ultimately comes out ?—Yes.

24529. And there is no accumulation in the filters, and you suggest to us that the 32 parts have been liquefied and digested—consumed ?—Yes.

24530. Of course, if the 32 parts have been digested, you have no hesitation in saying that the 8 parts put on the septic tanks in the other places have also been digested ?—Yes.

24531. Are you quite sure that that is possible; if you take the 32 parts that go on to your filter and you ignite them you will get some ash left, will you not ?—Yes.

24532. Do you suggest that the part which would be left, which probably would be a half of the 32 parts, is digestible by bacterial action ?—I do not know that it would be half; I do not know that it would be as much as half.

24533. Have you investigated that ?—No.

24534. Supposing it were half ?—There the fact remains that this material—thirty-two parts—does go on and has done for years, and by some process or another it has been dealt with, because you can take the filter to pieces and it is not there; as I say, it is held back on the top.

24535. One can quite conceive that if the surface is exceedingly fine the suspended matter would remain on the surface, that part of it might be digested, and that the remainder it is possible to remove by raking ?—No doubt there is a certain amount of accumulation, but it is so slight that it is not apparent.

24536. It is not appreciable ?—If it had been material these filters would have been raised up towards the distributors, but apparently they have not; the space betwee the filter surfaces and the fixed distributors being, as far as one can see, the same as at first.

24537. In your filter at Hanley you have not a specially fine substance on the surface; it is the same as at the bottom of the filter ?—We go down to one-eighth of an inch in the body of the filters.

24538. But you have not made a special difference ?—We have not made a special difference; we shall do so in the permanent works, however, using $\frac{1}{8}$ in. particles for the top and $\frac{1}{4}$ in. to $\frac{1}{2}$ in. for the body because of economy. Were it not for the cost I should recommend $\frac{1}{8}$ in. particles throughout.

24539. Have you found accumulation of the matter there ?—Oh, yes.

24540. And with material of that kind is it possible to form it into heaps ?—It is only forked up and raked.

24541. Mixed up with the material ?—No, only on the top, not allowed to go below.

24542. If it is forked over, the surface accumulations get so far into the bottom of the tank ?—Well, a little distance; a few inches down.

24543. Do you not think they are likely to be washed through ?—The object of forking is really to break up any little tenacious sediment which forms on the surface; that is all.

24544. Would it be possible to remove it frequently by raking it into heaps ?—It would be possible, but it does not seem to be necessary.

24545. Of course, that is really the whole question, that if you put a certain quantity of suspended matter on a filter of fine grade, the life of that filter may be reduced by the accumulations of undigested suspended matter; and the special interest in your evidence is that in your district it has been found possible to use this very fine material and yet not to be troubled by any of these accumulations ?—Yes.

24546. The evidence from other districts being strongly the other way ?—But have you had evidence from other districts in which small particles have been used ?

24547. Perhaps not quite so small as this ?—That is my point.

24548. But still very small; we had one particular instance where the material was small and where very rapidly the surface was choked; and although this was forked, and much of the matter removed ultimately a good deal of it got down into the body, so that the filter had to be abandoned ?—I have no examples of that except in the case of the large particle filter where you do get the

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solids into the middle and apparently when they do get into the middle of a filter they cannot be dealt with ; they must be washed away with the effluent or remain there ; it is only on the top apparently where they can be digested.

24549. I saw quite recently a percolating filter with absolutely sand material on the surface, upon which an effluent was put which was thoroughly clarified, chemically precipitated, and even in that case after working only a few days there was on the surface of the sand a thin film of deposited matter ?—Yes.

24550. Which they found it necessary to remove every week ; raked it into heaps and took it away ?—Do you know at what rate the sewage was being put on the filter ?

24551. At a very slow rate ; quite an exceptionally slow rate ?—Because you can clog any filter by increasing the rate of flow.

24552. In this case it was excessively slow. Of course we shall be greatly interested to hear from your district whether it is found practicable to continue to use the very fine material ; but evidently you yourself agree that where a fine material of that kind is used, there must be very complete clarification ?—Of course, it is desirable to have as complete clarification as possible, but in my experience it is not essential.

24553. Do you say to us that it is possible to increase considerably beyond the five to eight parts that you suggest as possible, that it is possible to increase the suspended matter beyond that point considerably, and still to use fine material ?—Certainly ; and that is done at Burslem ; we put thirty-two parts on to the filter there.

24554. Then what is the process of settlement there ?—Only a large detritus tank ; the sewage is pumped from a pump well, or rather a tank which is large enough to contain about 12 hours' flow, if not more ; but as a matter of fact it is never allowed to get full ; it passes into a detritus tank, and from there into this tank, which was originally designed as a subsidence tank, but is now used merely as a pump well ; and is never allowed to fill, so there is practically only detritus treatment there.

24555. And does this sewage so settled pass on to contact beds ?—On to filters.

24556. Yes, you limit the term filter to the percolating filters ?—Yes.

24557. Then it is not on contact filters, but on percolating filters ?—Quite so, yes.

24558. And in that case you put thirty-two parts on to the first filter ?—Yes.

24559. And only one part comes away from the second filter ?—Yes.

24560. And there is no accumulation ?—There is no accumulation.

24561. How long has that filter been going ?—That filter has been going now, I should think, five years ; and the size of the particles I think I give.

24562. Have you actually dug down into the first filter ?—Yes, and had specimens taken up from it ; not very lately ; that was when I reported upon the particular works.

24563. What age was that first filter when you then examined it ?—Eighteen months.

24564. It has been working since ?—I estimated at that time, taking into account the solids that went on to it, that three times the capacity of the filter itself in sludge had been consumed.

24565. We should like to see an analysis of the Burslem effluent going on to the first filter with its thirty-two parts, in order to know with regard to that suspended matter how much of it would be ash and how much organic ?—That could easily be done.

24566. Because if, for instance, half or third of it were indigestible, it is obvious, is it not, if it does not come away it must remain behind ?—Of course, if that is so it would get clogged, but that would only apply, strictly speaking, because the detritus is kept back.

24567. Do you mean that the proportion of mineral matter is largely taken away in the detritus tank ?—Oh, yes.

24568. You have not investigated how far the suspended matter passing away from the detritus tank would leave ash if it were burned ?—No.

24569. That seems rather an important point ?—The works are still there and they are available for any experiments that the Commission like to apply.

24570. That is a vital point, affecting the life of filters of all kinds, whether contact or percolating ; and hitherto it has been found that if the suspended matter does not come away the filter is bound to choke up because a large part of the suspended matter is not digestible by bacterial action even after passing through a detritus tank ?—Yes.

24571. Now, do you not find at Burslem that at times after the filter has been working several years a good deal more suspended matter com s out ; the figures you have given us are in the earlier period of the life of the tank. Have you any idea what the amount is now ?—I have not made any analyses very lately in this particular case, but my inspector reports regularly as regards the effluent and it has maintained, as far as appearance goes, its original standard the whole time.

24572. Just one other point. I think you expressed to Lord Iddesleigh the opinion that it was undesirable to mix up artificial filtration with land filtration ?—Yes.

24573. And that it was therefore undesirable to have a first filter followed by treatment on land ?—Yes.

24574. But I did not gather that you gave your reasons for that ; or if you did I am afraid I did not catch them ; would you mind telling us ?—Well, may I put a case ? It frequently happens ; it has happened once or twice in Staffordshire that works are designed, first, for septic tank treatment ; second, single contact treatment ; and, finally, land. Well, now, what I maintain is that the land, if it is suitable land, would deal with the septic tank effluent without the intervening stage of contact, and that this intervening stage is a needless expense, but by reason of its being introduced the Local Government Board will sanction a much smaller area of land than they otherwise would do ; they will sanction, I believe, something like 1,000 persons per acre. Now, I maintain that the fact of introducing single contact in no way helps that land if you are going to put that quantity of sewage on to it.

24575. You think you would have as much difficulty in passing that volume through the land whether it has gone to a contact bed or not ?—It is not so much the difficulty of passing through that volume as the difficulty of getting it nitrified, and that quantity of sewage on that area of land will not be nitrified, and the intervening process of single contact will not materially help the process in my opinion.

24576. The single contact which is interposed will bring about, of course, considerable purification ?—Certainly.

24577. It will bring about some digestion of the suspended matter which came through ?—Yes.

24578. So that the work to be done by the land will be less ?—Yes, but not sufficiently less to make it worth while.

24579. You would prefer a second contact filter to the land ?—If there is not sufficient area of land certainly, I do not think it is necessary to have a second filter, but if you have contact I certainly should have.

24580. I think you expressed that view yourself, that the single contact is insufficient ?—Yes, quite so.

24581. Then you must have either second contact or you must have this land treatment ?—Yes, or single filtration.

24582. Well, I do not quite see if the land is there and suitable, why it should not serve the purposes of a second contact filter ?—If it is of sufficient area.

24583. One is assuming ?—If it is of sufficient area and good land then I submit that contact is not necessary ; the land will do the whole thing.

24584. But the land would produce proportionately better results ; they would be better with a first contact bed than without ?—I do not think so.

24585. If it has certain purifying powers, and it has less to do, the final result would be better ?—The thing is this ; the great point which determines whether the

land will answer or not is not so much the quality of the material put on it, as the volume, and you cannot go beyond a certain volume even with very good land; you can go up to a considerable volume, but not to a 1,000 persons per acre, and the interposition of contact treatment will not materially help matters.

24586. Your objection is to the large volume proposed to be passed over the land?—Yes, if you like, use that area of land for what it is worth after septic tank treatment or chemical precipitation, which ever you like.

24587. And supplement?—And supplement it by single filtration or double contact in the case of the sewage flow beyond that which the land is capable of dealing with.

24588. Your view is really on the economical point?—Most certainly.

24589. You think it would be better to use the land as far as it may properly be used, and then supplement it by contact beds, rather than mix the two processes?—Quite so, or, as I should prefer, filters.

24590. Not because there is any objection other than the question of volume?—Yes, there is an objection, I maintain, because if you first pass it through a single contact bed you will get purification up to a point, but if you then put the sewage of anything approaching 1,000 persons on an acre, even if the land is phenomenally good, you will not improve the purification.

24591. Your objection is to the volume proposed to be put on the land?—It will only act as a mechanical strainer; you will get no further purification or nitrification.

24592. I think you said in cases where the Local Government Board did not insist upon land that they do insist upon an excessive area of artificial filters?—Yes.

24593. Can you point us to any case where there is an excessive area of artificial filters provided under their influence?—That has really only arisen lately; it is only lately that the Local Government Board have consented to consider the question of artificial filtration without land, and now they say, "Very well, we will sanction this scheme without land, but you must double your area of filters." Then, of course, we are no better off; we have twice the capital to spend.

24594. I see; then as a fact that has not been done?—It was to be done in one district; we made a very strong representation to the Local Government Board, and I do not know what position the Board will take, but I hope that they will sanction this scheme in the way that I suggest, namely, that they should sanction it provisionally, and if it is found that the area of filters provided does not give satisfactory results then the authority will extend.

24595. Are you able to tell us what the volume per cubic yard was in this case before the Local Government Board?—The practice is to base the estimate on a foot yard that is a square yard a foot deep, and I think the volume is fifty-six gallons per foot yard, but Mr. Willis will correct me if I am wrong.

24596. (*The Secretary.*) Twenty eight gallons without land?—Very well—they require twice that capacity without land.

24597. (*Colonel Harding.*) I suppose really their provision is this, that if there is land they will allow one contact; but if there is no land available they insist upon two contacts; is that what you mean by doubling the area of the filters?—That is not what I mean by it We say that single filtration at a certain rate of flow will give a high class effluent which will not be improved by land. The Board will sanction filtration or contact with the same capacity in each case and subsequent land treatment; if, however, land is not provided, then the alternative is double the capacity of filters or contact beds.

24598. You do not object where contact beds are used to there being double contact filtration; if there is no land you say that single contact is insufficient and that in your case you must have double?—No, I say single contact is not sufficient, but single filtration is.

24599. So that you are in entire agreement with the Local Government Board?—No, I say that the present requirements for filters are sufficient without land treatment to follow.

24600. You say that instead of contact filtration at all, you prefer percolating filters?—Yes.

24601. In which case a single filter is sufficient?—Of a certain depth, yes.

24602. Of a certain depth?—Yes.

24603. But this regulation I think does not apply to percolating filters, does it?—The Board make it apply to both; they only look to the cubic capacity, whether the treatment is by contact or by filtration.

24604. That is to say there should be the same quantity per cubic yard in either case?—In either case.

24605. Your claim is that two contact beds 5 feet deep are double the cost of a percolating bed 5 feet deep, and that you get the same results in either case?—I say double contact; not necessarily 5 feet in each filter; it does not mean that; I have thought it over; you do not require quite double the capacity in contact that you do in filters, but very nearly that.

24606. Supposing you had two contacts of 3 feet deep, and you were comparing those with a percolating filter 6 feet deep; of course, you have the same volume of material; do you think that the results of the filtration would be better in the percolating filter, and do you think that the volume to be passed through would be larger?—The results, taking corresponding volumes, would be immensely better in the filter.

24607. With corresponding volumes?—Yes, immensely better.

24608. Then to get equal results you would be able to bring through the percolating filter a much larger volume?—Yes, you would have to diminish your flow on to the contact beds about half to get the same result, or approaching the same result, as from the percolating filter.

24609. Well, any way these regulations of the Local Government Board are provisional, are they not?—Oh, I hope so.

24610. Depending upon experiments and the report of this Commission?—It would seem to be so, but regarding this point my work has long ago ceased to be experimental except for special sewages.

24611. (*Mr. Stafford.*) In reply to Question 19, what places are these you speak of: "As regards trade effluents, those of which I have had the most experience are the following." At what places are these works?—You mean the galvanising waste?

24612. Yes, and the brewery waste and chemical waste?—Well, the galvanising waste is in most of the towns in South Staffordshire.

24613. In most of the towns?—In Wolverhampton, Bilston, Tipton; in most of these towns where galvanising takes place. The brewery waste, as far as I am concerned, is chiefly at Lichfield, Stone, and Burslem, but at Burslem the quantity is not so very great compared with the sewage flow.

24614. And your chemical waste from works at most of these places, I suppose?—The chemical waste from the chemical works is at Oldbury. That is a very bad example of the absolute incapacity of the works very largely owing to the chemical waste.

24615. Have you any experience of the particular place in which the sewage is too acid to filter, because you speak of adding a certain amount of lime?—Yes, that is at Wolverhampton; it is quite impossible to put the Wolverhampton sewage through an artificial filter without first chemically precipitating.

24616. It is so acid?—Yes.

24617. Is that the only place?—Yes, the only place where it has been tried and stopped at once; it was quite impracticable; there was a proposal at Bilston to put down works of septic tank treatment and artificial filtration; I opposed the scheme on the ground of the acid waste in the sewage, and it was altered, so it will not be done there; they will now chemically precipitate there, but the same thing would have happened at Bilston that has happened at Wolverhampton unless they had altered their proposal.

24618. It is quite exceptional I suppose?—I think it would apply in all cases where these works exist; in some of the towns now they have not got works that you can

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call works where acid goes into the sewer, and in many cases it goes into the streams and not into the sewers at all ; of course, we are hoping to get it out of the streams and into the sewers ; then it will absolutely compel the authority to adopt chemical precipitation, unless where, as in the case of Birmingham, the sewage flow is so much greater than the waste, that it does not materially affect the question.

24619. You say, "Probably a high class effluent can only be obtained by means of a deeper filter than is usually found necessary, or, better still, perhaps, by double filtration through shallow filters." You are speaking of brewery works ?—Yes.

24620. What kind of filters are you referring to ?—Percolating filters formed of small particles.

24621. I think you referred to some experiments you are making at Stone with regard to treatment of septic tank effluent with some form of deodorising material Do you think we know sufficient about purifying bacteria to enable you to deal with evil smells without destroying the purifying bacteria used ?—Well, of course, that remains to be seen ; I have proved that the brewery sewage at Stone can be dealt with by a septic tank treatment and double filtration ; in that case, I do not think it could be done with single filtration except with a deep filter—and two shallow filters in my opinion are better than one deep one—but the nuisance is too great in that particular locality. If we cannot do it in the way I suggest it will put Stone to an enormous expense in getting land a long way away from the town and pumping sewage up to a height ; we are endeavouring to avoid that, and to some extent we have reason for it, because they have been adding permanganate of potash to these tank effluents for the purpose of limiting the smell, and they have succeeded in doing it materially. But, of course, that is too costly altogether, and what we hope to do it by is "oxychloros" advocated by Dr. Rideal. I have recommended my council to wait, for the purpose of seeing what is the result of this treatment if it should be adopted.

24622. Is this a germicide ?—It is a germicide if used in sufficient strength.

24623. But would it be of any use if used in insufficient strength ?—Oh, yes.

24624. As a deodoriser ?—Yes.

24625. You think you will get it to act as a deodoriser without being a germicide ?—I hope so.

24626. Have you made any experiments with it ?—Not with this sewage.

24627. With any sewage ?—No, I have not personally.

24628. This is something you cannot speak of from experience ?—An antiseptic can be used just up to a point merely as a deodorizer, but if you go any further——

24629. But what point is that ?—Of course, that has to be ascertained by experiment.

24630. My point is this, do we know enough about this purifying bacteria ?—As to know what will kill them ?

24631. Quite so ?—Well, I was just thinking of an example that I had on one occasion which rather led me to suppose that they were not so easily killed as one imagines ; it was in the case of a sewage which I thought would kill them and I found it did not ; I have just forgotten for a moment where it was. That is my impression, that they are not so easily damaged as one might suppose ; however, it will entirely depend upon the working of the experimental plant whether the authority will adopt the proposal.

24632. Why did you not try ordinary chemical purification treatment at Stone ?—For the same reason : you have to handle the sludge, and the works are so badly situated, that even in the handling of the sludge you have nuisance, and also in the distribution of the sewage, even chemically precipitated sewage.

24633. Yes, I see ?—They have been chemically precipitating ; that is what they have been doing.

24634. And they have been treating afterwards on contact beds ?—On filters, and my object in going into the matter was to see what could be done by septic tank treatment, to avoid the chemical precipitation of the sludge, and then it was found that this would add very much to the mischief from the nuisance point of view.

24635. It would be very interesting to find out whether you succeed in deodorising without destroying the germs ?—Of course, that is the thing one has to guard against.

24636. (*Major-General Carey.*) On Question 123, beyond the experiments at Burslem, have you had actual experience of the results of purifying the sewage in a percolating filter which has only previously passed through detritus tanks and a roughing filter ?—No, only Burslem.

24637. Your experience is limited to the Burslem experiment ?—It is with regard to that particular form of treatment, yes.

24638. Question 128 ; in estimating the area of percolating filters in terms of the number of gallons per square yard which is required for the treatment of ordinary sewage; what limit in the rate of supply to the filter per square yard do you suggest should be adopted for the average daily dry weather flow and storm sewage coming to the works, allowing for periods of rest. I observe that in Table IV they vary continually ?—Yes.

24639. Have you considered any limit in the number of gallons per square yard which should be put upon a filter ?—Of course, that will be regulated very much by the quality of the sewage ; but in the case of an ordinary domestic sewage I think you may for a long period with proper distribution ; of course, that is of vital importance ; for a long period you may work up to 200 gallons per yard with a filter something like five feet deep, but you may over-do that filter for a short period during storm times without materially injuring it ; of course, now and again it will be necessary to rest the filter, but the rest need only occupy a few days ; it is astonishing what a few days rest will do for a filter. I think 200 gallons per yard is a maximum for anything like continuous working, and then there must be perfect distribution.

24640. Would 200 gallons a yard give a sufficient area for treating the storm sewage as well as the dry weather flow ?—Oh, no.

24641. Do you suggest that the storm sewage should be treated separately ?—Yes. I think if you put it in this way, if you have a works based upon 100 gallons per yard or from 100 to 120, you may take it that such works will be sufficient to deal with three times the dry weather flow ; I mean five feet deep filters based upon from 100 to 120 gallons per superficial yard ; then you ought to provide for the extra flow special arrangements either in the shape of land or less elaborate and costly filters.

24642. (*Colonel Harding.*) Do I understand that if the filter area is based upon 100 to 120 gallons per yard that you may at times of storm increase that to three times the volume ?—Yes.

24643. (*Major General Carey.*) Up to three times the dry weather flow ?—Up to three times the dry weather flow. Of course, I am not dogmatising with regard to this at all ; I mean that is my impression ; and for that reason I think that the requirements of the Local Government Board as regards filters are sufficient, because that is about what it works out at.

24644. (*Colonel Harding.*) You think it quite practical to increase the volume to about 360 gallons ?—Only for a short period.

24645. Only for a short period, of course ?—If you continue with that you will rapidly deteriorate your effluent and you will ruin your filters.

24646. (*Major General Carey.*) Has the suggested limit a direct relation to the depth and cubic contents of the filter ?—It has a direct relation to the depth. I think that you will get the maximum efficiency, having regard to cost, by filters of about five feet deep, but if it is desirable for any reason, such as the character of the sewage, to increase that depth considerably, then I think you ought to have two filtrations in place of one. It is not desirable to have a filter much deeper than five or six feet ; if it is necessary to have one deeper than that I mean it is better to have two shallower ones, because you start with a fresh second filter in place of having a filter which is less aërated than otherwise would be the case. I have a case in point now of a scheme in North Staffordshire where nine feet filters are proposed, and I am urging the Local Government Board, in considering the scheme, to insist upon the same cubic capacity, but the works to be constructed on a basis of five feet or six feet filters at the outside, rather than nine feet ; that is to say, to provide the same cubic

capacity of filters, only not to make them nine feet deep; you would then get very much better results; first of all the sewage would not pass through so rapidly as in the case of a deep filter, because the deeper the filter with the same cubic contents the quicker the flow on to it, and I maintain that you do not require that depth to get high nitrification.

24647. Referring again to the question of contact beds in addition to land; if an area of land which has been acquired for sewage disposal is suitable but too limited, owing possibly to increase of population, would not the treatment by precipitation and primary artificial filtration relieve the land to an important extent and enable it to purify the sewage, with results which could not have been obtained by precipitation alone?—I do not think so; I am perfectly certain of that, because the chief element you have to consider is volume not quality after tank treatment, especially precipitation treatment.

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24648. Of course, we have numerous instances in the South of England where they have adopted the primary filters—at Beddington, Norwood, etc., in order to relieve the land, and I understood that they had been satisfactory; that is to say that they had done the work for which they were intended?—Well, I have a case in Leek where the sewage of 600 persons per acre is disposed of by downward filtration on sand beds with very first class results. What I maintain is that if one introduced between the tank treatment and the land treatment single contact one would not get the slightest difference in the way of improved results from the downward filtration beds.

24649. No relief would be given to the land by the intermediate treatment on the single contact filter?—Practically no relief. The land is either suitable or it is not; it is either sufficient or it is not, and single contact will not materially assist.

Mr. E. A. LETTS, D.Sc., F.I.C., PH.D., Professor of Chemistry at Queen's College, Belfast, called in and Examined.

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24650. (*Chairman.*). You have been engaged for some time past in investigations as to the most suitable method of treatment for the sewage of Belfast, where the problem of sewage purification is not exactly of the ordinary kind. Will you first tell us as briefly as possible the nature of the special circumstances which render the problem unusual?—The ordinary objects of sewage purification in cases where the resulting effluent eventually reaches a non-drinking water stream or body of water may, I think, be stated as follows:—First, the removal, as far as possible, of the suspended solids; secondly, the production of an effluent which shall not putrefy eventually; and, thirdly, that when thrown into a stream or body of water this effluent shall not act injuriously either by causing a deposit or a nuisance, or by depriving the water of its dissolved oxygen to such an extent that fish life is jeopardised. Broadly speaking, these objects are best attained after the removal of the suspended solids, by eventually submitting the liquid portions of the sewage to as radical a process of oxidation as possible, leading first to the formation of carbonic anhydride, and, secondly, to the formation of nitrates. These latter are very serviceable in hindering or preventing putrefactive changes, and their production in quantity should certainly be aimed at in those cases where the effluent passes only into a small body of water, but when the effluent is largely diluted, both the nitrates and also the free ammonia (which in itself is of no special importance as an impurity) may produce secondary effects, such as the encouragement of the growth of aquatic vegetation in large and sometimes in unmanageable quantities, the vegetation causing trouble either by blocking up the watercourse, or, in certain cases, by decomposing and giving rise to a nuisance. It is an effect of the latter kind which forms the difficulty at Belfast, the sewage from the city passing directly into the Lough, where it encourages the growth of certain green seaweeds, of which the most abundant and important is the Ulva Latissima. At certain seasons of the year these seaweeds are washed ashore in enormous quantities, and by their putrefaction cause a very serious and extensive nuisance. It is therefore clear that a method of sewage purification leading to the production of a highly nitrated effluent, or one containing much ammonia, while entirely satisfactory in the majority of cases, is not suitable for Belfast, and that some other method is desirable in which the resulting effluent shall be as free as possible from those substances which encourage the growth of green seaweeds.

24651. Do you know of any other places where the conditions are similar to those existing in Belfast Lough—I mean where these seaweeds are found in quantity and give rise to a nuisance?—Yes. In my previous evidence I drew attention to Dublin Bay, or rather to certain parts of Dublin Bay, where these seaweeds occur in considerable quantities, and at times give rise to a nuisance. Also, last summer during a tour round some of the chief English estuaries which Dr. Adeney and I made in connection with a report which we are preparing for the Commission on the pollution of tidal waters by sewage, we noticed several places where the green seaweeds were abundant and caused a nuisance, and also in the replies to a circular letter, sent at our request to the medical officers of health of a number of seaside or tidal localities, quite a number of others were mentioned. These we shall deal with fully in our report. I may also mention that a botanical acquaintance of mine who has recently gone to Barbadoes has written to tell me that the only *ulva* which he has seen there was growing in sea water polluted with sewage.

24652. And in all those localities where you have either yourself seen these green seaweeds, or have been told that they occur in quantity, sewage is discharged into the water, and, in your opinion, is the cause of their abundance?—Yes.

24653. Assuming that to be the case you consider that the ordinary methods of sewage purification, or at all events of those which lead to a strongly nitrated effluent, or one which contains much ammonia, to be unsuitable for Belfast and other localities where a seaweed nuisance occurs?—Yes, and I would go even further than that and suggest that the type of purification process employed for a given locality ought to vary according to the conditions there prevailing and the nature of the interests mainly involved. At least, in preparing an effluent for discharge into a non-drinking water stream I think that it is important to distinguish between the three following cases:—(1) An effluent passing into a non-fishery stream; (2) an effluent passing into a fishery stream; (3) an effluent passing into the sea where an *ulva* nuisance has to be avoided. In the first of these cases, which are perhaps the most important owing to the magnitude of the interests involved and at the same time are often the most difficult to deal with owing to the fact that the watercourses are frequently small, and may indeed consist chiefly if not entirely of the sewage effluent itself, the main object to be kept in view is the prevention of a nuisance, and in all probability that is best done by obtaining as highly a nitrated an effluent as possible. In these cases the dissolved oxygen present in the effluent as it leaves the purifying station is not a factor of prime importance, provided that nitrates are present in sufficient quantity to prevent subsequent putrescence. But in the second class of case the requirements are different, the presence of nitrates not being essential while dissolved oxygen is the important factor. Hence an effluent to be discharged into a fishery stream must, in addition to being non-putrescent and devoid of substances toxic to fish, be also sufficiently aerated; and I should regard aeration as a factor of prime importance in such cases. Then to return to the seaweed question, and also to cases where excessive and troublesome vegetation is produced in rivers, the chief object to be aimed at should be the removal from the sewage or effluent of those substances which encourage the growth of this vegetation—namely, ammonia and nitrates.

24654. Have you any suggestions to lay before the Commission as to how that may be done, and have you made any experiments on the matter?—Yes, both; and if you will allow me I will first of all describe the latter. In the evidence which I gave before the Commission when it visited Belfast I drew attention to the fact that in the treatment of sewage by contact beds a very considerable proportion of the combined nitrogen pre-

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sent in the original sewage disappears during the treatment, and I showed from the analyses which I had made of the dissolved gases that some of the nitrogen thus lost is found in the effluent as free nitrogen; while no doubt owing to the slight solubility of that gas in water a further quantity and probably most of the missing nitrogen escapes into the atmosphere in the gaseous state. I found as the mean of twelve series of analyses that the combined nitrogen present in the effluent (as free and albuminoid ammonia and nitrates), amounted to about 32 per cent. of the combined nitrogen (expressed in the same factors) occurring in the original sewage, leaving about 68 per cent. unaccounted for, or, rather, which can be accounted for on the assumption that it escaped in the gaseous state as free nitrogen. I also found that in six of these series of experiments (which were made under precisely the same conditions) the excess of nitrogen present in the effluent over that present in the original sewage amounted in weight to 0·272 parts per 100,000, while the loss of unoxidised nitrogen which had occurred during the treatment of the sewage amounted to 2·2 parts per 100,000, or that about 12 per cent. of missing nitrogen was thus accounted for, while in one particular case it amounted to nearly 20 per cent. I also drew attention to the very small quantity of nitrates present in the effluent from this method of treatment, which in the above series of analyses corresponded on the average with only about 1 per cent. of the total combined nitrogen present in the original sewage, and was actually less than the amount of nitrate found in the latter, which corresponded with about 4½ per cent. of the total combined nitrogen. These facts seemed to offer a strong indication of the lines on which to work out a method for so treating the Belfast sewage that an effluent containing a minimum amount of nitrates might be obtained; but the reduction in the amount of ammonia by double contact treatment was not very satisfactory, as it amounted to only about 51 per cent., and experiments which meanwhile had been made with the *ulva* had shown that it absorbed ammonia much faster than nitrates, and also that from sea water containing both of these substances all the ammonia was absorbed by the *ulva* long before the nitrate. Therefore it was of prime importance as regards the Belfast problem to endeavour to get rid of a higher proportion of ammonia from the sewage. In view of the results obtained in some of the Manchester experiments,* where a reduction of 84 per cent. had been obtained in the amount of this substance by treatment of the sewage in a septic tank previous to submitting it to the contact beds, it was decided to experiment in the same direction at Belfast, and a small plant was accordingly erected there, consisting of a closed septic tank and two contact beds filled with broken brick fragments. With this plant a series of experiments was conducted during a period of about four months, and the results were eminently satisfactory as regards the loss of free ammonia, which now amounted to 87 per cent., while the loss of albuminoid ammonia was also, though slightly, higher than obtained by contact bed treatment only, namely, 73 per cent. instead of 71 per cent., and so, too, the loss of nitrogen in the gaseous state, calculated in the manner I have described and amounting to about 60½ per cent. instead of 58. It was thus evident that the purification effected by the septic tanks plus double contact bed treatment was much greater than that effected by double contact bed treatment only, and for that reason alone, to say nothing of the superiority of the former method in dealing with the suspended solids, was to be recommended for Belfast. But the effluent now contained nitrates, and, as these afford the necessary nitrogenous food for the *ulva*, their removal was important. How could this difficulty be overcome? The researches of Gayon and Dupetit, of Tacke, Adeney, and some other observers appeared to give a clue to a method, for these have shown that nitrates are decomposed when in contact with a putrefying liquid, with evolution of gaseous nitrogen or its oxides, carbonic anhydride being formed at the same time. It remained, however, to be seen whether a reaction of this kind would occur with sufficient rapidity and under conditions of such a kind as would enable it to be utilised in practice for the destruction of the nitrates in a sewage effluent. It was necessary, in fact, to submit the whole question to an experimental inquiry, and in the first place it was decided to investigate the effects of adding a definite quantity of a pure nitrate to the effluent from a septic tank (as representing a liquid in an active state of putrefaction). The experiments on this point were conducted in collaboration with Mr. R. F. Blake, F.I.C., F.C.S., and Mr. J. H. Totton, M.A., and consisted of:—(1) A study of the chemical changes which occur when a nitrate is added to the effluent from a septic tank. (2) An investigation as to the cause of these changes. (3) A few experiments on the action of specific micro-organisms as regards their effects on nitrate in a sterilised but putrescible medium.

* Report of Rivers Department, January 22nd, 1903. Table 7.

A.—The Chemical Changes which occur when Potassium Nitrate is added to the Effluent from a Septic Tank.

The method of experiment consisted in completely filling two similar bottles (which were then tightly stoppered)—one with the septic tank effluent alone and the other with the same effluent plus an accurately measured volume of a strong solution of potassium nitrate, one cubic centimetre of which was equivalent to ten milligrams of nitric nitrogen—allowing the two bottles so filled to remain at the temperature of the laboratory for a given interval of time, and then examining their contents quantitatively, and more particularly as regards the dissolved gases.

With one exception all the experiments were made with mixtures of potassium nitrate and septic tank effluent, containing 2·5 parts of nitric nitrogen per 100,000 of mixture in the case of the nitrated samples.

The analysis of the dissolved gases was both tedious and troublesome in many of the experiments, owing partly to the complexity of the gas mixtures to be examined and partly to the small quantities available for analysis. Moreover, in the earlier experiments certain difficulties were encountered which rendered the complete analysis of the dissolved gases very uncertain, and as a consequence there is some doubt as to the extent of the evolution of nitrogen in the earlier experiments of the nitrated series.

Table 1 contains the chief results obtained, while on Table 2 some of them are presented in a different form, together with certain other data.

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TABLE 1.

DISSOLVED GASES FOUND IN SEPTIC TANK EFFLUENTS (A) WITH ADDED POTASSIUM NITRATE AND (B) ALONE AFTER CERTAIN INTERVALS OF TIME.

(Results in cubic centimetres per litre at 0° C. and 760 m.m.).

		1.	2.	3.	4.	5.	6.
	Nitric nitrogen added in parts per 100,000	2·5	5·0	2·5	2·5	Non-Aërated. 2·5	Aërated. 2·5
	Time interval in hours	48	24	24	24	24	24
A Nitrated sample.	Carbonic anhydride	169·97	155·68	153·34	158·01	165·85	149·63
	Nitrogen	38·12?	29·40	34·21?	32·41	36·16	33·53
	Nitric oxide	?	?	6·99	6·31	0·00	0·00
	Marsh gas	?	?	?	3·37	2·63	0·00
	Oxygen	0·00	0·00	0·00	0·00	0·00	0·00
B Septic tank effluent.	Carbonic anhydride	126·68	150·99	118·10	127·31	120·44	92·52
	Nitrogen	18·84	18·86	15·62	16·55	16·48	13·94
	Marsh gas	?	?	1·91*	2·92	1·72	0·14?
	Oxygen	0·00	0·00	0·00	0·00	0·00	5·33
Differences.	Carbonic anhydride (excess in nitrated sample).	43·29	4·69	35·24	30·70	45·40	57·11
	Nitrogen as nitrogen and nitric oxide (excess in nitrated sample).	19·28?	10·54?	22·08?	19·12	19·68	19·59
	Marsh gas (excess in nitrated sample)	?	?	?	0·45	0·91	−0·14?

* Marsh Gas 1·48 / Hydrogen 0·43 } 1·91.

TABLE 2.

EVOLUTION OF NITROGEN EITHER AS SUCH, OR IN THE FORM OF GASEOUS OXIDES, FROM SEPTIC TANK EFFLUENTS WITH ADDED POTASSIUM NITRATE. ALSO OTHER CHEMICAL CHANGES OCCURRING.

(Dissolved gases in cubic centimetres per litre. Other quantities in parts per 100,000.)

		1.	2.	3.	4.	5.	6.
	Nitric nitrogen added in parts per 100,000	2·5	5·0	2·5	2·5	2·5	2·5
	Time interval in hours	48	24	24	24	24	24
Dissolved gases.	Carbonic anhydride evolved in nitrate sample	43·29	4·69	35·24	30·70	45·40	57·11
	,, ,, theoretical evolution*	49·80	99·60	49·80	49·80	49·80	55·13
	Nitrogen evolved in nitrated sample	19·28?	10·54?	22·08	19·12	19·68	19·59
	Theoretical evolution	19·90	39·80	19·90	19·90	19·90	19·90
Free and albumenoid ammonia.	Nitrogen as free ammonia in septic tank effluent alone.	2·14	3·43	1·98	2·06	1·84	—
	Nitrogen as albuminoid ammonia in septic tank effluent alone.	0·58	0·58	0·49	0·66	0·50	—
	Nitrogen as free ammonia in septic tank effluent plus nitrate.	1·48	3·30	1·89	1·81	1·58	—
	Nitrogen as albuminoid ammonia in septic tank effluent plus nitrate.	0·66	0·74	0·57	0·66	0·66	—
	Excess of nitrogen as free ammonia in septic tank effluent alone.	0·66	0·13	0·09	0·25	0·26	—
	Excess of nitrogen as albuminoid ammonia in nitrated sample.	0·08	0·16	0·08	0·00	0·16	—
Nitrites.	Nitrogen as nitrite in nitrated sample	—	0·11	0·05	0·00	0·00	0·00
	,, ,, ,, non-nitrated sample	—	0·00	0·00	0·00	0·00	0·00

* *I.e.*, the carbonic anhydride equivalent to the oxygen of the added nitrate

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The chief general conclusions arrived at may be summed up as follows:—

(1) Potassium nitrate (and no doubt any other nitrate likely to be produced in a sewage effluent) is decomposed by the septic tank effluent, and the nitric nitrogen is evolved, sometimes entirely as free nitrogen, sometimes partly as nitric oxide. Nitrous oxide may also be formed, but the evidence on that point is not as yet conclusive.* The action seems to vary with different samples of septic tank effluent, but in four of the eight experiments the theoretical quantity of nitrogen (corresponding with the added nitrate) was found either as free nitrogen alone or along with nitric oxide.

There is no evidence from our experiments to show that any considerable quantity of these gases is produced from either the free ammonia or the organic nitrogen present in the septic tank effluent.

(2) The general character of the change is that of a combustion, the oxygen of the nitrate eventually appearing either partly or entirely in the form of carbonic anhydride.

(3) In some of the experiments a little nitrite was produced, but in the majority none was found at their conclusion.

(4) The destruction of the nitrate occurs with remarkable rapidity, and in most of the experiments the whole of the added nitrate—equivalent to 2·5 parts of nitric nitrogen per 100,000 of mixture—was decomposed in 24 hours.

A remarkable exception to this rule is, however, noticed in the case of experiment 2, in which the quantity of nitrate added was twice as great as in the other experiments. Here the evolution of carbonic anhydride is trifling, and that of the nitrogen very considerably less than in the other experiments.

It is, perhaps, not safe to arrive at general conclusions from a single experiment, but it would at least seem probable that, while a certain quantity of nitrate is readily decomposed and acts as an oxidising agent, burning up the carbon of the sewage to carbonic anhydride, there is a limit to the quantity which can thus be decomposed, beyond which excess of nitrate retards or possibly prevents the action.

(5) In addition to the decomposition of the nitrate and evolution of carbonic anhydride, the fermenting liquid experiences other changes.

There is always a *loss* of free ammonia, and as a rule a *gain* in albuminoid ammonia, but the former generally exceeds the latter. Thus in six experiments † the average loss of free ammonia amounted to 0·266 part per 100,000, while the corresponding gain in albuminoid ammonia was only 0·166, or not much more than half the preceding figure.

It may also be mentioned that in two of the experiments marsh gas was found, not only in the septic tank effluent, but also in the nitrated fluid, and it is somewhat remarkable that more of the gas was found in the latter than in the former.

Towards the end of the investigation the effects of aëration were studied. Parallel experiments were made, in one of which the septic tank effluent was thoroughly aërated before mixing it with the nitrate, while in the other the same quantity of nitrate was added to the non-aërated effluent. In both experiments the whole of the nitrate was decomposed in 24 hours with evolution of the equivalent quantity of nitrogen gas. In the aërated sample no marsh gas was formed, but a considerable excess of carbonic anhydride was produced, the total volume per litre of fluid being 57·1 c.c., whereas the amount corresponding with the added nitrate plus the oxygen dissolved from the air was 49·8 + 5·33 = 55·13. In the non-aërated sample some marsh gas was formed, but considerably less carbonic anhydride.

The results obtained in this investigation suggest in part, at all events, an explanation of the production of free nitrogen in the contact beds commonly employed in the purification of sewage. These during the period when they are in contact with air, no doubt become charged with nitrates, and the latter are then destroyed when the beds are filled with sewage.

Attention may also be specially drawn to the experiment in which the nitrate was decomposed in the aërated septic tank effluent, as it has been stated that nitrates are *not* decomposed by a putrefying liquid under aerobic conditions.

In practice it might be difficult to avoid at least partial aeration in obtaining or subsequently dealing with a nitrated effluent, but the experiment referred to shows that aeration does not hinder the decomposition of the nitrate.*

B.—Cause of the Decomposition of Nitrates when in Contact with a Putrefying Liquid.

In order to ascertain whether the action was brought about entirely by the vital processes of micro-organisms, and was not due to enzymes excreted by them or to purely chemical changes, an apparatus was devised in which the septic tank effluent was passed through a Chamberland filter and thence into a sterilised flask, from which it was drawn by a vacuum pump into two sterilised tubes of sufficient capacity, one of which contained a measured volume of the nitrate solution, and these tubes when filled were closed by pinch-cocks applied to indiarubber junctions. At the end of 66 hours, analyses were made of the dissolved gases contained in the contents of both tubes, when the following results were obtained (in cubic centimetres per litre):—

	Nitrated Sample.	Non-Nitrated Sample.
Carbonic anhydride -	92·12	94·45
Nitrogen - - -	1·62	2·00
Oxygen - - -	0·00	0·00

The figures are not absolutely identical, but are nearly so.

The reason for the excess of dissolved gases in the non-nitrated sample is easily explained, as the liquid yielding these gases was drawn from the lower layers in the flask, which had not been exposed to the vacuum so long as the upper layers, from which the liquid for the nitrated sample was drawn.

The somewhat large quantity of carbonic anhydride found in the analysis is no doubt due to the presence of carbonates or bicarbonates in the fluid, and not to free carbonic anhydride.†

It is, however, quite obvious that no nitrate was decomposed, and the results of this experiment appear to be decisive.

The septic tank effluent deprived of the micro-organisms which it contains has no action upon a nitrate, and the decomposition of the latter must be caused entirely by the vital processes of certain micro-organisms and not by enzymic or chemical action.

C.—The Micro-Organisms which reduce Nitrates with Evolution of Nitrogen Gas or Oxides of Nitrogen.

Gayon, Springer, Deheraine, Maquenne, and others have isolated organisms from putrefying liquids which decompose nitrates with evolution of nitrogen or its oxides, but, so far as can be judged from the printed abstracts of their work, the identification of the species with known forms was either wanting or was incomplete. It occurred to us that as the action is one of reduction it would be worth while to study the effects of those micro-organisms which are known to cause the evolution of hydrogen, such as B. *Amylobacter*, B. *Butyricus* (Botkin) B. *Lactis aërogenes*, and B. *Coli communis*, and as pure cultures of the two latter happened to be available, experiments were made with them.

An apparatus was constructed which permitted the introduction of pure cultures into a vessel filled with sterilised broth containing potassium nitrate from which the dissolved gases had been removed by boiling out in a vacuum.

With this apparatus experiments were first made on the action of pure cultures of B. *Coli communis* and

* Gayon and Dupetit found all three gases.

† One of these is not contained in the above table, as an accident occurred during the analysis of the dissolved gases.

* It is, however, possible, and indeed probable, that all the dissolved oxygen in the aerated sample had disappeared before the dissolved gases were examined, so that the liquid was then under anærobic conditions.

† In extracting the dissolved gases a certain quantity of acid was always added to decompose carbonates and bicarbonates.

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B. *Lactis aërogenes* on broth alone. These were conducted at ordinary temperatures, and the fluid examined for dissolved gases as soon as a few bubbles of liberated gas had made their appearance. The dissolved gases were found (after removing carbonic anhydride) to consist entirely of hydrogen.

Experiments were then made with cultures of the same organisms and nitrated broth, and although they are not as yet completed, the results so far obtained show that B. *Coli communis* liberates nitrogen from a nitrate in broth culture; B. *Lactis aërogenes* does not do so.

I desire to express my thanks to Professor Lorrain Smith, who supplied the pure cultures and gave most valuable assistance and advice during the bacteriological part of the investigation.

The experiments just described indicated that it is quite possible to destroy the nitrates in a sewage effluent with considerable rapidity in such a way as to prevent them from serving as a food or manure for vegetation, as it need scarcely be mentioned that free nitrogen is not assimilated by plants except in one or two exceptional cases. They also point to a method of sewage purification suitable for a locality like Belfast, where the main object is the prevention of excessive vegetable growth—the broad features of such a method being (1) purification of a part of the sewage by the usual methods, for instance, by septic tank treatment, followed either by treatment on contact beds or by a "sprinkler" or continuous filter, whereby the greater part both of the free ammonia and the organic nitrogen are got rid of, while a certain amount of nitrate is produced; and (2) treatment of this effluent with a certain proportion either of the original sewage or of septic tank effluent to destroy these nitrates. As a preliminary step towards the working out of a practical method for most advantageously combining the two processes, it was decided to investigate the changes which occur on mixing definite proportions of the effluent resulting from treatment of sewage by septic tank and double contact beds with the septic tank effluent itself. Unfortunately the time at my disposal for these first experiments was very limited, and was insufficient for a complete examination of the liquids operated on. All that could be done was the determination of nitrates and nitrites (a) in the nitrated effluent alone, and (b) in mixtures of this with the effluent from a septic tank in certain proportions after an interval of 24 hours, while (c) in one or two cases nitrates and nitrites were also determined in the nitrated effluent alone after 24 hours. The experiments with the mixtures were conducted in bottles which were about half-filled, and no precautions were taken to exclude air, a point which should be noted, as it has, I believe, been asserted that the reduction of nitrates to nitrogen does not occur under aerobic conditions. After an interval of 24 hours in each case, during which the bottle remained at the laboratory temperature, determinations of nitrite and nitrate were again made, and the results calculated so as to give the quantities of these present, not in 100,000 parts of the mixture, but in 100,000 parts of the nitrated effluent contained in the mixture.

The following table contains the results of these experiments:—

Loss of Nitrogen as Nitrogen Gas or Gaseous Oxides of Nitrogen occurring in a Mixture of the Septic Tank Effluent with the same after Treatment on Contact Beds.

Number of Experiment.	Nitrogen present as Nitrite and Nitrate (parts per 100,000). In the Nitrated Effluent. On Mixing. Nitrite	On Mixing. Nitrate	On Mixing. Total	After 24 hours. Nitrite	After 24 hours. Nitrate	After 24 hours. Total	Composition of the Mixture.	(Calculated as present) in the same Effluent 24 hours after mixing it with the Septic Tank Effluent. Nitrite	Nitrate	Total	Loss of Nitrogen. Actual (parts per 100,000)	Percentage.
1 ...	—	—	0·82	—	—	0·82	4 volumes Nitrated Effluent and 1 volume Septic Tank Effluent.	—	—	0·55	0·27	33
2 ...	0	0·66	0·66	0	0·66	0·66	4 ditto ditto	0·22	0·03	0·25	0·41	62
3 ...	0	0·58	0·58	0	0·58	0·58	2 ditto ditto	0·0	0·09	0·09	0·49	85
4 ...	0	0·82	0·82	—	—	—	4 ditto ditto	0·0	0·0	0·0	0·82	100
							3 ditto ditto	0·0	trace	traces	nearly 0·82	nearly 100
5 ...	traces	nearly 2·16	2·16	—	—	—	4 ditto ditto	0,87	0·93	1·80	0·36	17
							3 ditto ditto	0·84	0·93	1·77	0·39	18

It will be seen that in every case nitrates were reduced and partly, at least, converted into nitrogen gas, while in some of the experiments all the nitrates were thus disposed of. Some other features in the results may be drawn attention to. Thus the greatest loss of nitrogen occurred when no nitrites were produced, and conversely the least loss of nitrogen took place when nitrites were formed in considerable quantities. Also it will be seen that no reduction of the nitrates occurred in the nitrated effluent alone when kept for 24 hours, indicating, I presume, that the organic matters originally present had been oxidised for the time being, at all events as far as possible.

A second series of experiments was made in a similar way to those just described, with the difference, however, that the effluent from a "sprinkler" was substituted for the effluent from the contact beds previously employed. The subjoined table contains the results of this series:—

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LOSS OF NITROGEN AS NITROGEN GAS OR GASEOUS OXIDES OF NITROGEN OCCURRING IN A MIXTURE OF THE SEPTIC TANK EFFLUENT WITH THE SAME AFTER TREATMENT BY A SPRINKLER.

Number of Experiment.	Nitrogen present as Nitrites and Nitrates (parts per 100,000). In the Nitrated Effluent as—			Composition of the Mixture.	(Calculated as present) in the same Effluent 24 hours after mixing it with the Septic Tank Effluent.			Loss of Nitrogen. Actual (parts per 100,000).	Loss of Nitrogen. Percentage
	Nitrite.	Nitrate.	Total.		Nitrite.	Nitrate.	Total.		
1 ...	—	—	1·318	4 vols. Nitrated Effluent and 1 vol. Septic Tank Effluent	—	—	1·132	0·186	14·1
2 ...	none	1·318	1·318	4 „ „ „ „	0·25	0 987	1·237	0·083	6·1
3 ...	traces	—	1·515	4 „ „ „ „	0·50	0·837	1·337	0·178	11·9
4 ...	0·125	1·275	1·400	3 „ „ „ „	0·53	0·678	1·208	0·192	13·7
				1 „ „ „ „	0·80	0·102	0·902	0·498	35·6
5 ...	traces	—	1·980	4 „ „ „ „	traces	1·850	1·850	0·130	6·6
6 ...	0·100	2·370	2·470	4 „ „ „ „	0·125	2·035	2·160	0·310	12·5

The results of this series are, on the whole, very different from those of the first, the reduction of nitrates to nitrogen being so much less. The explanation of this difference very possibly lies in the fact that whereas in the first series the nitrated effluent was known by experience to contain only small quantities of dissolved oxygen (1·5 c.c. per litre—mean of three determinations), that used in the second was much more highly aërated (6·5 3c.c. per litre—mean of three determinations). But at the same time it should be remarked that the proportion of nitrate present in the two nitrated effluents was very much higher in the second than in the first series, with the exception of No. 5 of the first series, where the smallest loss of nitrogen of the series occurred. It is somewhat difficult to find an explanation for the incomplete reduction of nitrates in all the experiments of the second and in some experiments of the first series, contrasted with the complete reduction which occurred in the experiments already described in which potassium nitrate was added (in concentrated solution) to the septic tank effluent. The conditions, however, in these last-named experiments were by no means the same as those under which the others were made. In the first place, in all the experiments with potassium nitrate the bottles were filled to the brim and then stoppered, while in the second place, as the nitrate was added in a concentrated solution, the ratio of oxidisable matter to nitrate was obviously much higher in these experiments than those in which a relatively large volume of the nitrated effluent (presumably fairly free from readily oxidisable matters) was mixed with a small volume of the septic tank effluent. From the results of the experiments just described it is evident that, given sufficient time and sufficiently large storage tanks, the effluent obtained during the treatment of sewage can be made to react upon each other in such a way that the nitrates in the finished effluent can at least partially be resolved into nitrogen gas. But it is scarcely necessary to say that one of the chief objects to be kept in view in the treatment of sewage is to "hurry up" the purifying processes as rapidly as possible, while another is to reduce the volume of the sewage under treatment to the smallest practicable limit. My next experiments were therefore made with the view of ascertaining to what extent, economy in both time and storage capacity was possible as regards the destruction of nitrates. They were suggested by the views I have already advanced as regards the formation of nitrogen gas in the effluent from the contact beds, viz., that during the resting periods of these beds, when they are exposed to air, they become charged with nitrates, and that these nitrates are rapidly destroyed when the beds are filled with sewage. It seemed therefore possible that that by submitting a mixture of a nitrated effluent with either sewage itself or the effluent from a septic tank to treatment on a contact bed, a double effect might result, namely, destruction of nitrates in the first and purification of the second, and, possibly, a triple effect, in that the denitrefying processes might be accelerated. An experimental "sprinkler" of the Ridgeway pattern having by this time been installed at Belfast, and a preliminary examination of its effluent having shown that nitrates were present in abundance, it was decided to employ this sprinkler as the source of the nitrated effluent. A small contact bed filled with finely graded broken brick material was constructed below the bed of this sprinkler, together with a mixing tank and an arrangement for regulating the flow into the latter of any desired proportions of the sprinkler and septic tank effluents, and in the first experiments equal volumes of the two were employed. The arrangement, therefore, was of this kind. A certain volume of septic tank effluent passed through the sprinkler and its bed, and thence made its way into the mixing tank, while (in the first experiments) the same volume of untreated septic tank effluent also passed into the latter. Thence the mixture of the two flowed into the contact, or "denitrefying bed," where it remained for three hours, after which it was drawn off, the bed allowed to remain empty for three hours, and the same cycle of operations again repeated. As the same liquid, namely, the septic tank effluent, was the starting point from which both the effluents from the sprinkler and the denitrefying bed were obtained, the chemical condition of these latter could be referred at once to that of the former. In all, six series of experiments were made, the results of which are given in the following tables. But it should be mentioned that while the conditions were similar in the first four series,* they were somewhat different in the two last. In the former, approximately equal volumes of the effluents from the septic tank and sprinkler passed on to the denitrefying bed, and the rate of flow of the sprinkler corresponded with 260 gallons per square yard (of sprinkler bed) per 24 hours, while in the latter four volumes of septic tank effluent mixed with three volumes of sprinkler effluent passed on to the denitrefying bed, and the rate of flow of the sprinkler was diminished to 195 gallons per square yard. It is scarcely necessary to draw attention to the improvement in the purification effected by the sprinkler, both as regards reduction in the amount of free and albuminoid ammonia and the increased production of nitrate which occurred when its rate of flow was lessened; but it is worthy of notice that this reduction of flow also corresponds with increased purification as regards free ammonia in the denitrefying bed, in spite of the fact that a larger proportion of the septic tank effluent was present in the mixture flowing on to this bed.

* With the exception of No. 1 when the denitrefying bed was quite new, and evidently not in working order.

EFFECTS PRODUCED (A) WHEN A SEPTIC TANK EFFLUENT IS TREATED BY A SPRINKLER AND (B) WHEN A MIXTURE OF THE SEPTIC TANK AND SPRINKLER EFFLUENTS IS TREATED ON A "DENITREFYING BED."

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Series.	Date (1905).	Time of Collection.	Nature of Sample.	Parts per 100,000.				
				Oxygen Absorbed. (4 hrs. at 80° F.)	Nitrogen as:—			
					Free Ammonia.	Absorbed Ammonia.	Nitrates.	Nitrites.
1	Jan. 25th	4 a.m.	Septic Tank Effluent - -	7·98	3·46	0·70	—	—
1	Jan. 25th	4 a.m.	Sprinkler Effluent - -	2·68	1·48	0·39	1·32	—
1	Jan. 25th	7 a.m.	Denitrefying Bed Effluent -	3·05	1·48	0·37	0·82	0·0
2	Feb. 1st	4 a.m.	Septic Tank Effluent - -	6·24	3·30	0·74	—	—
2	Feb. 1st	4 a.m.	Sprinkler Effluent - -	2·59	1·07	0·33	1·32	traces
2	Feb. 1st	7 a.m.	Denitrefying Bed Effluent -	2·96	1·40	0·37	0·00	0·0
3	Feb. 8th	4 a.m.	Septic Tank Effluent - -	6·88	2·96	0·74	—	—
3	Feb. 8th	4 a.m.	Sprinkler Effluent - -	2·56	0·74	0·37	1·51	traces
3	Feb. 8th	7 a.m.	Denitrefying Bed Effluent -	3·04	1·32	0·37	0·00	0·0
4	Feb. 15th	4 a.m.	Septic Tank Effluent - -	6·88	3·62	0·82	—	—
4	Feb. 15th	4 a.m.	Sprinkler Effluent - -	2·56	1·43	0·41	1·40	0·12
4	Feb. 15th	7 a.m.	Denitrefying Bed Effluent -	3·04	1·48	0·45	0·00	0·0
5	Feb. 21st	10 p.m.	Septic Tank Effluent - -	5·95	2·58	0·62	—	—
5	Feb. 21st	10 p.m.	Sprinkler Effluent - -	2·27	0·49	0·29	1 98	traces
5	Feb. 22nd	1 a.m.	Denitrefying Bed Effluent -	2·49	0·95	0·37	0·00	0·0
6	Feb. 28th	10 p.m.	Septic Tank Effluent - -	5·33	3·29	0·47	—	—
6	Feb. 28th	10 p.m.	Sprinkler Effluent - -	2·07	0·56	0·27	2·46	0·01
6	Mar. 1st	1 a.m.	Denitrefying Bed Effluent -	2·27	0·93	0·27	0·25	0·0

It is evident that the effects anticipated on theoretical grounds did in point of fact occur, and to an extent which I had scarcely ventured to hope for. Excluding the results of the first experiment (which was made only a few days after starting the denitrefying bed, and evidently before it had got into working order), complete disappearance of the nitrates occurred in four of the experiments, and a loss of nearly 90 per cent. in the last. But it should be noted that in this last experiment an unusually high proportion of nitrates was produced by the sprinkler, while an unusually low proportion of organic matter was present in the septic tank effluent. It will be seen that the purification effected on the septic tank effluent in the denitrefying bed does not fall far short of the purification effected in the same effluent by treatment with the sprinkler. The reduction in the amount of free ammonia is, it is true, somewhat less, but that of the albuminoid ammonia is almost identical in the two. But I think that the most interesting point in these experiments is the remarkable rapidity with which the nitrates disappeared from the sprinkler effluent in the denitrefying bed—as I have ventured to call it for that reason. It may be objected that the term implies a difference between an ordinary contact bed and the bed in question, but the difference does not lie in the bed itself, but in the method of working it. It is clear from the experiments just described, that when it is charged with a liquid containing nitrates, plus easily oxidisable organic matter, rapid reduction of the former occurs, with, no doubt, corresponding oxidation of the latter; while, on the other hand, if no nitrates are present in the liquid to start with, the bed may assume an entirely opposite function, and nitrates be actually formed, as occurs, for instance, when the septic tank effluent is treated by contact beds. It seems to me, therefore, that the oxidising and purifying effects of the contact beds must depend to some—and possibly to a large—extent upon the production and eventual destruction of nitrates, which serve as carriers of oxygen from the air to the organic matter, thus functioning (to some extent at all events) like the oxides of nitrogen in the manufacture of vitriol.

I am aware that the experiments I have described above on the treatment of sewage in such a way that, while sufficient purification is effected, the resulting effluent shall contain no nitrates, are incomplete, for while the second part of the problem seems easy of accomplishment, the first part is by no means so simple. Much more work will, I suspect, be necessary before an entirely satisfactory solution of the problem is arrived at, but I venture to think that the lines on which further investigations should be pursued are sufficiently clearly indicated by the experiments I have described.

I may conclude this part of my evidence by drawing attention to the diagram I have prepared to illustrate the results of different methods of sewage treatment, as found by me at Belfast. In this diagram the different nitrogenous constituents, both of the original sewage and of the resulting effluents, are represented by differently marked areas, and the percentage amount of each by the size of these areas. It will be seen how greatly the effects vary, according to the method of purification employed. (See end of evidence for diagram).

24655. Have you done any other work on the subject of denitrification?—Yes, along with Mr. R. Blake, I have made a careful study of the changes which occur spontaneously in a nitrated effluent when kept, for it seemed to us that the nature of these changes and the rate at which they occur are important from a practical point of view, and more especially in relation to some of the large manufacturing districts where such effluents

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are discharged into sluggish streams, the waters of which may not reach the sea for some days.

24656. Have these effluents the power of remaining free from a nuisance, even if undiluted, during the whole of their journey seawards?—Any laboratory experiments on a question of this kind as a rule only partially reproduce the actual state of affairs, for they are conducted under static conditions, and of necessity ignore the effects of flow and the consequent gaseous interchanges and reactions occurring between the liquid and the bed of the stream on the one hand, and the liquid and the air on the other. However, it seemed worth while to make some laboratory experiments, as they would probably give at least a general indication of the changes likely to occur under actual conditions, as well as an idea of the rate at which those changes would take place. In deciding as to the conditions under which such experiments should be made we were guided by the consideration that in all probability the changes at the surface of a body of a nitrated effluent would be different from those occurring in the lower layers, and we therefore decided to perform two sets of experiments, the first under anaërobic conditions and the second under aërobic conditions. For the first of them a number of Winchester quart bottles were filled to the brim with the effluent, placed in an incubator at 15 deg. C., and after a few hours were then stoppered. For the second the effluent was also placed in Winchester quart bottles, but these were only partly filled, and were shaken with air from time to time. Three series of experiments with different samples of the nitrated effluent were made under anaërobic conditions, but the time at our disposal only enabled us to perform one series under aërobic conditions. The results of the different determinations made in all four series are collected in the following table:—

CHANGES OCCURRING IN A NITRATED EFFLUENT WHEN KEPT AT 15° C.

[The Effluent resulted from the Treatment of a Septic Tank Effluent by a Ridgeway Sprinkler.]

Series.	Date.	Time.	Dissolved Gases (c.c. per Litre at N.T.P.).				"Oxygen Absorbed" (4 hrs. at 80° Fahr.).	Nitrogen (parts per 100,000) as:—			
			CO_2	O_2	N_2	Total.		Free Ammonia.	Alb'd. Ammonia.	Nitrite.	Nitrate
A (Anaërobic)	Feb. 22nd, 1905	Shortly after collection	50·04	6·55	17·81	74·40	2·27	0·49	0·29	traces	1·98
	„ 27th, „	5 days „ „	55·61	0·00	18·01	73·62	1·67	0·41	0·22	„	2·10
	Mar. 3rd, „	9 „ „ „	14·94*	0·10*	18·43	—	—	—	—	„	—
	„ 14th, „	20 „ „ „	61·18	0·00	19·74	80·92	—	0·49	0·20	„	1·85
	„ 24th, „	30 „ „ „	64·78	0·00	21·85	86·63	—	0·58	0·16	„	1·65
A (Aërobic)	Feb. 22nd, „	Shortly after collection	50·04	6·55	17·81	74·40	2·27	0·49	0·29	„	1·98
	„ 27th, „	5 days „ „	—	—	—	—	2·06	0·44	0·25	„	2·02
	Mar. 14th, „	20 „ „ „	—	—	—	—	—	0·18	0·25	1·0(?)	2·06
	„ 24th, „	30 „ „ „	—	—	—	—	—	0·00	0·16	0·00	2·50
B (Anaërobic)	Mar. 8th, „	Shortly after collection	39·21	6·84	17·21	63·26	—	0·44	0·19	traces	2·31
	„ 9th, „	24 hours „ „	40·46	5·13	17·10	62·69	—	—	—	—	—
	„ 13th, „	5 days „ „	44·93	0·08	17·60	62·61	—	—	—	—	—
	„ 15th, „	7 „ „ „	—	—	—	—	—	0·36	0·15	—	2·31
	„ 30th, „	22 „ „ „	51·04	0·00	19·51	75·55	—	0·48	0·14	0·0	2·18
C (Anaërobic)	Mar. 16th, „	Shortly after collection	44·46	6·20	16·52	67·18	1·25	0·46	0·10	traces	1·18
	„ 20th, „	4 days „ „	49·38	0·50	16·53	66·41	1·12	—	—	„	1·29
	„ 23th, „	7 „ „ „	50·57	0·00	16·86	67·43	0·98	0·33	0·07	„	1·51

In the anaërobic series it is evident that the first change of any importance is the disappearance of the dissolved oxygen, which occurs with relative rapidity, and was practically complete in four or five days. Most of this oxygen is converted, it will be seen, into carbonic anhydride, but some of it is apparently converted into nitrate, as in two of the series rather more nitrate was found after five days than was present at first. Later, denitrification commences, more carbon is burnt up, and nitrogen is liberated in the gaseous state. This change occurs, however, very slowly, and is by no means complete at the end of a month. In addition to these changes there is a slight but definite increase in free ammonia and a slight decrease in albuminoid ammonia. The two, however, do not completely balance each other, and probably a little nitrogen is lost in the free state. The following "balance-sheet" may be written as regards the first or A series:—

Carbonic anhydride at finish	64·78 c.c. per litre	
„ „ „ start	50·04 „ „	
Gain in carbonic anhydride	14·74	
Free nitrogen at finish	21·85 c.c. per litre	
„ „ „ start	17·81 „ „	
Gain in free nitrogen	4·04	

Carbonic anhydride equivalent to free oxygen disappearing	6·55 c.c. per litre	
Carbonic anhydride equivalent to the loss of nitric nitrogen (0·33 parts per 100,000)	6·57 „ „	
	13·12	
Free nitrogen corresponding with the nitric nitrogen disappearing	2·63 „ „	
Free nitrogen corresponding with the difference between the nitrogen as free and albuimnoid ammonia at start and finish (0·04 parts per 100,000)	0·33 „ „	
	2·96	

* For this analysis the sample was drawn from the middle layer of liquid and not from the lower layers as in the previous analyses, as it was thought that the sediment might have affected the dissolved oxygen in the latter, and the trace of oxygen found is probably accounted for in this way. Moreover, in order to avoid the disturbing effects of nitrites on the dissolved oxygen, no acid was added when boiling out the dissolved gases. This explains the low proportion of carbonic anhydride found.

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The difference in the balance as regards carbonic anhydride, shows that rather more of this gas is evolved than can be explained by slow combustion due both to dissolved oxygen, and the oxygen equivalent to the nitric nitrogen, and a similar remark applies to the nitrogen. The excess in both cases may possibly be accounted for by evolution from purely fermentative causes, but it is small when referred to the volume of liquid actually analysed (200 c.c.), and the possibility of experimental errors must not be ignored.

In series B (anaërobic), there would appear to be fermentative evolution of some carbonic anhydride and nitrogen, as in series A (anaërobic).

In series C (anaërobic), the gain in carbonic anhydride very closely approximates the loss in dissolved oxygen, and there is apparently a very slight evolution of nitrogen. On the other hand the gain in nitrate is rather more than can be accounted for by the loss of free and albuminoid ammonia.

In the aërobic series the changes, so far as they can be followed, are different, but here gasometric analysis is no longer of service, and the usual but coarser methods of analysis can alone be employed. It will be seen that the nitrates increased in amount while the free ammonia decreased, and there was also a decrease in the albuminoid ammonia. The gain in nitric nitrogen very nearly corresponds with the loss of ammoniacal nitrogen. The balances stand thus:—

Nitrogen as free ammonia at start - - - -	0·49
„ „ „ finish - - - -	0·00
Loss of ammoniacal nitrogen - - - -	0·49
Nitrogen as albuminoid ammonia at start - -	0·29
„ „ „ finish - -	0·16
Loss of albuminoid nitrogen - - - - -	0·13
Nitrogen as nitrate at finish - - - - -	2·50
„ „ start- - - - - -	1·98
Gain in nitric nitrogen - - - - -	0·52

The results of the experiments just described indicate that no nuisance is likely to arise from a sufficiently nitrated effluent, even under the most unfavourable conditions, but, on the other hand, such an effluent might, if thrown in large volumes into the waters of a fishery stream, act injuriously, as its dissolved oxygen disappears with by no means inconsiderable rapidity. The extent to which it would absorb oxygen from the air, and so counterbalance this effect, would of course depend upon a variety of circumstances, of which depth of stream and rapidity of flow are probably the most important.

24657. Have you anything else to bring before us?—The only other matter I wish to mention is with reference to the volumetric method which Mr. Blake and I have devised for determining the dissolved oxygen in all classes of natural waters and in sewage effluents. That method is fully described in the Appendix which I present, so that I need not now go into the matter further than to express the hope that much more work will be done in future on the dissolved oxygen in our streams and rivers than appears to have been done in the past, because I think that a better idea of their condition in relation to active pollution can be formed from a knowledge of this factor than by any other single method of analysis. Then, too, the amount of dissolved oxygen which will disappear from a given sewage effluent in a certain time is of considerable importance in relation to the effects of the effluent on a stream, and more particularly so in the case of fishery streams. It is quite possible that neglect of such determinations has been due to the want of a sufficiently simple and reliable method, and I shall be glad if the process we have devised will be found to supply this want.

24658. I understand that you are able to give us some particulars with regard to the Belfast Sewage Works?—Yes.

24659. What is the population draining to those works?—304,000, but the sewage from 50,577 only is being treated at present, as the works are in an experimental stage, and a large area of land (70–80 acres) is being reclaimed from the sea to furnish sufficient space for the treatment of all the sewage. No more tanks or beds can be constructed until this is done, as all the space now available is occupied by the present experimental plant.

24660. What is the system of drainage? Is the storm water either wholly or partially drained into a separate system?—No; practically the whole rainfall from the streets and other impervious surfaces goes into the sewers.

24661. Is there any infiltration of subsoil water into the sewers?—There is a leakage of river water into the main drainage system, which some time ago I estimated from the salinity to be about 15 per cent. of the whole sewage passing to the outfall. Some of this, however, is not leakage, but is water taken from the river for condensing purposes, and then thrown into the sewer. The immediate neighbourhood of Belfast is hilly, and in rainy weather a large quantity of water finds its way into the sewers—leading occasionally to very serious floods in the city.

24662. What is the water supply per head, and from what source does it come?—About thirty gallons per head. The present supply is chiefly derived from upland surface drainage from the hills in the neighbourhood of Belfast. The new supply will come from the Mourne Mountain district.

24663. Is it hard or soft water?—The present supply is fairly soft. Total hardness, about 7 grains per gallon, temporary hardness, 3–4; permanent hardness, 4–3. The new supply is softer, as the gathering ground is largely granite.

24664. Has the flow of sewage to the works been gauged?—The flow has not been accurately gauged. Dry weather flow is about eleven million gallons in summer and winter.

24665. Can you say what the maximum and minimum dry weather rates of flow are?—No.

24666. Do you know what the maximum wet weather rate of flow has been, and during how many hours it continued?—Observations of this kind have only just been commenced.

24667. What is the largest number of gallons which have passed the last storm overflow and reached the works in twenty-four hours?—From the low level area about twenty-eight million gallons. No record is kept for the high level, as only part is pumped.

24668. How many gallons of trade effluents enter the sewers daily, and what is the nature of these effluents? Have you analytical figures?—The number of gallons of trade effluents entering the sewers is not known. The only important trade effluent is the "pot ale" of the distilleries. An interesting effect of this effluent when introduced into a sewer came under my notice some years ago. The pot ale from one of the Belfast distilleries—a very large one—was strongly acid before discharge, but was no serious nuisance in itself. The sludge in the sewer contained, as usual, much ferrous sulphide, but was also in itself no nuisance. But the effect of the acid pot ale on the sludge was to disengage much sulphuretted hydrogen, with the result that a serious nuisance was caused. No analytical figures available.

24669. Has the Corporation framed any rules for the reception of trade effluents into sewers?—No; except as regards their temperatures.

24670. Is it found that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume, or otherwise?—The available data are as yet insufficient to enable me to reply to this question fully. But lately substances of a tarry, or creosoty, nature have occasionally made their appearance in the sewage in considerable quantities, and were diverted from the purification plant, fearing trouble.

24671. In dry weather what is the average amount of suspended matter in the sewage, and what are the highest and lowest figures, in parts per 100,000?—I have not sufficient data to say.

24672. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—I can give an average analysis for the period

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November, 1902, to January, 1903, and an average of two analyses made in July, 1904. The figures are :—

PARTS PER 100,000.—November, 1902, to January, 1903. Average of 9 Weekly Analyses.

—	Nitrogen as :—		Oxygen absorbed, 4 hours at 80° F.	Chlorine.
	Free Ammonia.	Albuminoid Ammonia.		
Screened and settled sewage - -	2·29	0·92	6·95	59·0

July 1904.—Mean of 2 Analyses.

—	Nitrogen as :—		Oxygen absorbed, 4 hours at 80° F.	—
	Free Ammonia.	Albuminoid Ammonia.		
Crude sewage - - - - - -	2·47	1·28	10·30	—
Screened and settled sewage - -	2·76	0·95	7·95	—

24673. How do you think "strength" of sewage as affecting purification is best expressed or measured?—That is a most difficult, if not an impossible, question to answer comprehensively, as it seems to me that a sewage may be "strong" in several different ways in relation to purification, of which the chief are: (1) Suspended solids; (2) putrescible organic matter; (3) free or saline ammonia. The first two of these are important in relation to any system of purification; the third only in special cases like Belfast, where the chief object to be aimed at is the prevention of vegetable growths in the waters into which the effluent is discharged. As is well known, the average figures given by the Rivers Pollution Commission for the sewage of water-closet towns are as follow, in parts per 100,000 :—

Solids.	Chlorine.	Organic.		Ammonia.	Total Combined Nitrogen.	Suspended Matters.		
		Carbon.	Nitrogen.			Mineral.	Organic.	Total.
72·2	10·66	4·7	2·20	6·7	7·73	24·2	20·5	44·7

It is interesting in relation to the question of the "strength" of sewage to compare these figures with the results obtained within recent years in some of the large town :—

—	Oxygen absorbed, 4 hours at 80° F.	Chlorine.	Free and Saline Ammonia.	Albuminoid Ammonia.	Suspended Solids.	Total Organic Nitrogen.
Manchester* - - -	9·96–12·11	17·3–20·1	2·58–3·17	0·57–0·76	(?)	(?)
Leeds† - - - - -	12·71	—	3·37	1·48	63·1	(?)
Birmingham‡ - - -	9·85–16·92	10·8–23·9	2·27–3·14 (1)	0·99–1·45 (2)	47·5–59·6	4·06–6·88
Belfast§ - - - -	9·01	—	2·13 (1)	0·89 (2)	15·4	1·53
Belfast‖ - - - -	9·19	—	1·97 (1)	1·24 (2)	34·27	—

From these analyses it is evident that the figure given by the Rivers Pollution Commission for the free or saline ammonia is between twice and three times the amount actually present in the sewage of these four towns. I should, therefore, be inclined to regard a town sewage as "strong" in this factor if the amount exceeded, say, 3·5 parts per 100,000. As regards the suspended solids, the data upon which to form anything like a definite conclusion as to what constitutes "strength" are very meagre; but I should be inclined to regard a sewage containing anything over 50 parts per 100,000 as decidedly "strong" in respect of this factor. Coming now to the question of "strength" in relation to putrescibility, the difficulty at once arises as to how this factor should be arrived at. Suppose, however, for the moment, that the "oxygen absorbed test" be taken as the index, the lowest average amount found at Manchester, Birmingham, and Belfast is fairly uniform, and corresponds with between 9-10 parts per 100,000. The average figures given for the

* Weekly averages hourly of samples analysed once daily from April 1st, 1903, to March 30th, 1904. The figures are from the Annual Report of the Rivers Department, where they are given in grains per gallon.

† Average of analyses referring to period from March 26th to June 30th, 1900. The figures are from the City of Leeds Report on Sewage Disposal, July, 1900, where they are given in grains per gallon.

‡ Typical analyses given in Appendix 9c (p. 534) of this Commission's Reports, Vol. 3. The figures refer to four different sewers.

§ Average of analyses of *screened and settled* sewage made from January—June, 1902.

‖ Average of analyses of *crude sewage* made from December, 1903, to February, 1904.

(1) The figures refer to *nitrogen as* free from ammonia.

(2) The figures refer to *nitrogen as* albuminoid ammonia.

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London sewage* vary in a most remarkable way from 4·83 to 14·48, but the mean of these extremes is 9·6—practically agreeing with the lowest average amounts found in the three large towns just mentioned. Therefore, I think it may be fairly argued that "strength" in relation to this factor may be defined as anything above 10 parts per 100,000. It may now be of interest to give what appear to be typical examples of "strong" sewages in relation to each of the three factors discussed above.

1.—Sewages "strong" in Free or Saline Ammonia.

	Water Supply.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed.	Suspended Solids.
Hampton	22½	79·32	15·2 (organic)	—	—
Burgess Hill	18	17·20	4·0	8·03 (3 hours)	101·41
Newmarket	20	15·50	0·7	10·0 (15 m. at 140°F)	80·0
Guildford	20-30	11·53	3·58	17·03	—

2.—Sewages "strong" in Suspended Solids.

	Water Supply.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed.	Suspended Solids.
Newton-in-Makerfield	15	4·28	2·06	21·80	153·0
Burgess Hill	18	17·20	4·0	8·03	101·41
Maidstone	16½	4·95	0·74	11·15	81·0
Newmarket	20	15·50	0·7	10·0 (15 m. at 140°F)	80·0

3.—Sewages "strong" as regards the "Oxygen Absorbed" Test.

	Water Supply.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed.	Suspended Solids.
Malvern	25	4·0	0·2	33·08 (2 hours)	—
Newton-in-Makerfield	15	4·28	2·06	21·80	153·0
Guildford	20-30	11·53	3·58	17·03	—
Walsall	35	2·81	1·62	16·35	76·72

The figures in each case are taken from Appendix 9, Vol. 3, of the interim report of this Commission.

The point which I wish to bring out is that a sewage "strong" in any one of these factors is not necessarily "strong" in all. Thus, the sewage of Malvern, judged by the oxygen absorbed test is remarkably strong, but yet it contains a low proportion of albuminoid ammonia, and not an excessive quantity of free or saline ammonia. The sewage of Burgess Hill shows great strength as regards suspended solids, while judged by the oxygen absorbed test it is weak. While the Newmarket sewage is remarkably strong as regards free ammonia, it is by no means strong in relation to the oxygen absorbed test or in its content of albuminoid ammonia. As to the measurement of "strength" in relation to purification, there is, of course, no difficulty in determining any of the factors already discussed; but I am under the impression that the *crux* of the question lies in the determination of the amount of putrescible organic matter, and I do not believe that any chemist who has worked much at sewage analyses, or who has really considered how his results should be interpreted, will be inclined to pin his faith either to the oxygen absorbed test (in any of its forms) or to determinations of the albuminoid ammonia or the organic nitrogen, as furnishing a true index to the amount of putrescible organic matter. It appears to me that the only correct and rational method for measuring this factor should depend upon the determination of the actual amount of oxygen which the putrescible matter will eventually absorb. As to how this may best be done, I prefer to leave to my friend, Dr. Adeney, who has devoted a great deal of time and attention to the subject, and who, I understand, proposes to give special evidence on the subject.

24674. Can you say whether the sewage of Belfast is always alkaline?—All samples as yet analysed have been tested, and have been found to be alkaline.

24675. With regard to the question of storm water sewage, do you think it possible to have a standard form of storm water overflow?—The City Surveyor is introducing such in Belfast. The overflow is to come into operation when the flow in the sewer is six times the ordinary dry weather rate.

24676. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case?—Yes.

24677. Is the Belfast sewage settled, and, if so, how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids?—Yes; the sewage is settled in a large underground reservoir, which at present receives the sewage during the period

* The Experimental Bacterial Treatment of London Sewage. Being an account of the experiments carried out by the London County Council between the years 1892-1903.

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when discharge is not taking place, that is to say, for about 8½ hours on each tide; but during discharge (which occurs from the time of high water until half an hour after half ebb) a portion of the sewage is discharged without any settlement. An average of twelve analyses gave :—

PARTS PER 100,000.

Nitrogen as :—			Oxygen Absorbed, 4 hours at 80° F.	Suspended Solids.
Free Ammonia.	Albuminoid Ammonia.	Total Nitrogen (Kjeldahl).		
2·13	0·89	3·66	9·01	15·4

24678. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—I am of the opinion that the heavy portion of the suspended matter should be removed as a first operation.

24679. What is the manurial value of the Belfast sludge?—No sludging is done as yet. It all goes into the sea.

24680. Have you had any experience of the working of septic tanks?—The Belfast plant is entirely experimental as yet, and our experience with it is scarcely sufficient to enable me to speak authoritatively on the working of septic tanks.

24681. As regards contact beds, do you think it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely?—Any construction which makes the interior watertight and stable is suitable, but considerations regarding fracture of foundations, necessity of economising space, materials most readily procurable, etc., would decide the best methods to be adopted in a given case.

24682. What do you find to be the best filtering materials? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed?—An experimental plant, consisting of an open septic tank and a number of small contact beds (each 12 ft. by 10½ ft. and 2½ ft. deep) has been installed at Belfast in order to test the effects of different materials. The materials used are broken bricks, freestone, whinstone, limestone, clinker, and coke. The beds are arranged in pairs, so that the effects of double contact can be investigated. Most of the upper series are filled with fragments of "medium" size, while those of the lower series are filled with "fine" fragments. In order to include in this series of experiments, the effect of the size of the fragments, as well as those of the materials, a double set of the above beds has been filled with the same material (limestone), arranged thus :—One upper bed of "coarse" fragments, coupled with a lower bed of "medium" fragments. One upper bed of "medium" fragments, coupled with a lower bed of "fine" fragments. The "coarse" fragments were such as passed through a riddle 2½ in. in mesh, but did not pass through one of 1½ in. mesh. The "medium" fragments (of all the materials) were such as passed through this latter, but did not pass trough a riddle with ½ in. mesh, while the "fine" fragments (of all the materials) were such as passed through the ½ in. mesh, but did not pass through one of ⅛ in. The experiments are not yet completed, but the results obtained up to the present time are given in the subjoined table, together with some previous results, in which the effects of brick and coke fragments are contrasted or partly contrasted, as both of the lower beds were filled with brick fragments, while one of the upper beds was filled with coke and one with brick. It should be mentioned that the period of contact in each bed, and resting period of each bed, was about three hours; and also that the samples were taken simultaneously from all the beds, which were all filled at the same time with the same sewage after septic tank treatment.

EXPERIMENTS ON THE USE OF DIFFERENT MATERIALS IN CONTACT BEDS.

Liquid Examined.	Nature of Material.	Grade.	Parts per 100,000				
			Suspended Solids.	Nitrogen as :—			Oxygen Absorbed 4 hrs at 80° F.
				Free Ammonia.	Albd. Ammonia.	Nitrates.	
Crude sewage	—	—	34·07	1·97	1·24	0·13	9·19
Screened and settled sewage	—	—	—	2·19	0·85	0·09	7·26
Septic tank effluent	—	—	11·37	2·70	0·67	—	6·16
Effluent from double contact	Broken brick	Medium & Fine	0·66	0·32	0·25	0·76	1·44
„ „ „	Freestone	„ „	—	1·03	0·33	—	2·50
„ „ „	Whinstone	„ „	—	0·85	0·29	—	1·97
„ „ „	Clinker	„ „	—	1·40	0·38	—	2·30
„ „ „	Coke	„ „	—	1·07	0·33	—	1·99
„ „ „	Limestone	„ „	—	1·31	0·24	0·47	2·31
„ „ „	„	Coarse & Medium	—	0·96	0·21	0·42	1·75

OLDER EXPERIMENTS.

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Liquid Examined.	Nature of Material.	Grade.	Parts per 100,000				
			Suspended Solids.	Nitrogen as :—			Oxygen Absorbed 4 hrs. at 80° F.
				Free Ammonia.	Albd. Ammonia.	Nitrates,	
Screened and settled sewage -	—	—	12·9	2·00	0·72	0·04	7·76
Effluent from double contact -	Broken Brick -	Coarse & Medium	3·3	0·89	0·19	0·04	2·24
Screened and settled sewage -	—	—	22·8	2·55	1·41	0·44	12·77
Effluent from double contact -	Upper Beds - Coke - - Lower Beds - Broken Brick -	Coarse & Medium	5·2	1·48	0·17	0·00	3·80

The best results have clearly been obtained by the use of the broken brick material, whether tested by the purification obtained in free ammonia or in "oxygen absorbed." The appearance of the effluent from this material is also best, that is to say, it is clearest. On the whole, the worst results were obtained with the free-stone. The other materials show intermediate results, and with some of these (especially coke and clinker) it should be pointed out that the number of comparative experiments made is insufficient as yet to warrant definite conclusions. The results of the experiments with limestone are interesting and rather unexpected, as better purification was obtained with the coarser fragments than with the finer. As regards the question of durability of materials, our experiments at Belfast have demonstrated that coke disintegrates rapidly. We have not had any trouble in this respect with the broken bricks, and beds filled with that material in 1899 are in as good a condition now as when they were first set to work. We formed a bad opinion on general grounds of some large beds filled with destructor clinker, and for some time they were thrown out of action. This material, however, as obtained at Belfast, is of inferior quality, and disintegrates somewhat rapidly. The limestone we have used is hard, and, so far as our experience goes, does not disintegrate. It should be a good material for all places where the removal of the free or saline ammonia is not of importance.

24683. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary and secondary contact beds?—I have not gone into this question experimentally.

24684. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent?—This will depend upon (1) the nature of the tank effluent; (2) the definition of a "satisfactory" effluent; (3) how the effluent is to be disposed of; but, of course, 2 and 3 are inter-dependent. The following figures were obtained by me at Belfast as the mean of twelve series of analyses made during the winter and summer of 1902:—

Nature of Sample.	Parts per 100,000.*							Cubic Centimetres per Litre.†		
	Nitrogen as: —				Oxygen Absorbed Test, 4 hours at 80° F.			Dissolved Gases.‡		
	Free Ammonia.	Albuminoid Ammonia.	Total (Kjeldahl)	Nitrate.	3 Minutes.	4 Hours.	Incubator Test 3 Minutes.	Carbonic Anhydride.	Oxygen.	Nitrogen
eened and settled sewage	2·13	0·89	3·66	0·14	2·87	9·01	6·67	106·12	0·01	17·93
uent from upper bed -	1·55	0·52	2·36	—	1·64	4·74	3·55	115·51	0·00	19·14
„ „ lower bed -	1·04	0·26	1·59	0·03	0·92	2·62	1·38	111·39	0.03	20·00

PARTS PER 100,000.

Nature of Sample.	Solids.*						
	In Suspension.			In Solution.			Total.
	Fixed.	Volatile.	Total.	Fixed.	Volatile.	Total.	—
Screened and settled sewage -	3·2	12·2	15·4	137·9	32·6	170·5	185·9
Effluent from lower bed - -	1·2	2·3	3·5	138·2	22·6	160·8	164·3

RATIOS :—

Fixed : Volatile. In the Sewage. In suspension 1 : 3·8. In solution 1 : 0·24.
„ „ „ Effluent. „ „ 1 : 1·9. „ „ 1 : 0·16.
Suspended : Dissolved. „ Sewage 1 : 11.
„ „ „ Effluent 1 : 46.

* Mean of 12 series of analyses. † Mean of 6 series of analyses.
‡ The dissolved gases also contained at times hydrogen and marsh gas in small quantities. These were determined but are not included in the nitrogen.

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I do not consider that the effluent from first contact in the above experiments was sufficiently pure to be thrown into a *small* and *clean* non-drinking water stream.

24685. Are there any chemical poisons in the final effluent from the Belfast works?—No.

24686. What is the average amount of suspended matter in the primary bed effluent and in the secondary bed effluent? Does most of this suspended matter come out with the first flush or not?—The suspended matter in primary bed effluent has not been determined. I have given the figures for the secondary bed effluent. The results obtained were average results on samples taken every few minutes during discharge. No doubt a good deal of suspended matter comes out with the first rush of liquid from the contact beds; but I have made no special experiments on its amount.

24687. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—Complaints have been made, but I do not believe that the smell complained of came from the contact beds at all, but from refuse which was being tipped. There is, of course, a slight smell at times when a bed is being filled; but I do not think it could be noticed except close to the bed.

24688. As regards continuous or percolating filters, do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on the filters?—I have made no direct experiments on this point with a continuous filter, but from the greater readiness with which a septic tank effluent nitrifies in a contact bed, contrasted with the positive de nitrification which may occur when sewage itself passes directly on to a contact bed, I am strongly of the opinion that the septic tank forms an important preliminary step in the treatment of sewage by a continuous filter, preparing the liquid in some way which I do not think has been as yet explained for nitrification. But apart from this altogether, there is the question of the suspended solids, which must, I think, be more satisfactorily removed by a preliminary tank treatment.

24689. Do you find any nuisance from the treatment of sewage on percolating filters? Have any complaints been made?—A slight nuisance has been observed if a septic tank effluent is used. This might, I think, be considerable in the case of a large installation of septic tanks and continuous filters. No complaints have been made in Belfast at present, but we are only working on an experimental scale at present.*

24690. (*Sir William Ramsay.*) You speak in 24651 of green seaweeds causing a nuisance. I do not remember that the character of the nuisance has ever been explained?—I think I have given that in former evidence; but shall I repeat it again?

24691. I think it might be well if you were to tell us very shortly; because this will form a report of itself; your evidence and that of a number of other witnesses that we are examining just now; it would therefore complete it if you told us what sort of nuisance exists now?—Well, the nuisance occurs when the seaweed collects on the margins of the loch, mainly in a submerged condition. If it is dry there is no nuisance at all; but if it remains wet and submerged, or more or less submerged, then a serious nuisance occurs in consequence of its fermentation. That fermentation occurs, according to the work that I have done, in two different stages. First of all there is a rush of carbonic anhydride, with production of fatty acids, more particularly of propionic acid, so that you get an acid mixture resulting. Then apparently there is a subsequent fermentation of a distinct character whereby the sulphates, I think, of the sea-water are reduced to sulphides. These sulphides are then acted upon by the propionic and other fatty acids (the products of the first fermentation), with the result that sulphuretted hydrogen is produced. It is the sulphuretted hydrogen really which constitutes the nuisance. Perhaps I may draw the attention of the Commission to the fact that I think this seaweed nuisance is much more generally present on our coasts than is believed. In the trip which Dr. Adeney and I took on behalf of the Commission round some of the chief English estuaries last August we noticed it in quite a number of places.

24692. That the presence of seaweed was a nuisance?—That the presence of seaweed was a nuisance; and Southampton, I think, is a very good second to Belfast.

24693. Is it complained of at Southampton?—In a vague kind of way they say there is a nuisance; but they do not seem to connect it particularly with the seaweed.

24694. Have you found any effect upon the health of the population at Belfast or Southampton?—Well it is one of those questions that doctors are very chary about pronouncing an opinion upon; they all agree that it causes a lowering effect upon the general health of the population; want of appetite, and headaches, and that sort of thing; but they do not go so far as to say that it produces any specific disease*.

24695. In your answer to question 24653 there is a sentence which I daresay you would like to modify: "I should regard aeration as a factor of prime importance in such cases." It is towards the end of the answer, in discussing the effluent being toxic to fish or not. I suppose you would qualify that by saying that as long as the effluent does not itself absorb oxygen, it is not detrimental to fish life?—As long as it does not absorb oxygen—well, what I meant to convey there was that the effluent to start with ought to possess a certain degree of aeration.

24696. Which is not reduced by standing?—Not materially reduced on standing in presence of air.

24697. That is, I think, not quite clear?—Is that not quite clear?

24698. That is right, I think. On table 1, question 24654 [p. 430] I should like to ask if you have ever noticed any hydrogen evolved along with carbonic anhydride and nitrogen from the nitrified sample?—There is a footnote there from which you will find that hydrogen is produced.

24699. From the septic tank effluent there is hydrogen produced. You have analysed on one occasion the septic tank effluent under the heading 3 B; it refers to 1·91 of marsh gas?—Yes, that is the septic tank effluent alone.

24700. And that contains little hydrogen; was it tested for at other times?—Oh, yes, always tested for.

24701. But this was the only occasion on which it was found?—I think so.

24702. You find, I think, that free nitrogen is generally evolved in considerable quantity. Do you regard as the reason of that the decomposition of the nitrites?—Nitrate.

24703. Yes, but is there not nitrite of ammonium produced at one state of the stage which, as one knows, goes into nitrogen and water when heated?—Not in my experiments; I have very seldom observed the production of nitrite. You will find later on that some nitrites have been formed; but if you will look at table 2 I think that it is there—Yes, towards the bottom. Nitrogen as nitrite in nitrated sample—You will see that on two occasions there was a little nitrite present at the end of the 24 hours, but on all the other occasions there was none.

24704. Yes, but as a transitional stage in the formation of nitrogen, do you not think that the presence of nitrite is essential? The only chemical reason one can give for the evolution of nitrogen is the presence of nitrite at some stage or other and its decomposition; it may not be possible to detect it?—We have not been able to detect it.

24705. It looks unlikely that a nitrate should be reduced to nitrogen?—My own feeling about it after doing a good deal of work on the subject, is that the nitrate goes straight into nitrogen without intermediate formation of nitrite. I have no direct proof further than the fact that in three out of the five experiments no nitrite was found at the end of 24 hours, but the whole

* During a recent visit to the Birmingham sewage works (July, 1905) I was much struck by the practically complete absence of smell from both the sedimenting and septic tanks, through which the sewage of about 800,000 of a population was passing. A considerable proportion of the effluent was being treated on percolating filters, but there again practically no smell was apparent.

* It should however be stated that several cases of typhoid fever have occurred along the Belfast foreshores which cannot be traced to an impure milk or water supply.

of the nitrate had been decomposed with practically theoretical evolution of nitrogen gas.

24706. It is a theoretical point?—My experience on the whole has been that if nitrite formation occurs, you get less nitrogen gas; it seems to block the formation of nitrogen.

24707. It is a purely theoretical point, of course. On the same question (24654) you speak about loss of free ammonia and gain in albuminoid ammonia; was there any change in the quantity of nitric nitrogen?—What I have stated [end of under 1st general conclusion p. 594] is "There is no evidence from our experiments to show that any considerable quantity of these gases (nitrogen or its oxides) is produced from either the free ammonia or the organic nitrogen present in the septic tank effluent," but I have drawn attention [under 5] to the fact that in all the experiments there was always a *loss* of free ammonia, and as a rule a *gain* in albuminoid ammonia. Perhaps I may draw your attention to Section B, p. 594, as indicating that the reduction of nitrates is not a chemical process; I mean not a simple chemical process, but that it really is a biological process.

24708. Some experiments made by Dr. McGowan showed that Pasteur-filtered sewage underwent no change whatever; no oxidation?—I was not aware of those experiments.

24709. That the organisms are wanting; there is no oxidation even when the——

24710. (*Dr. McGowan.*) They have not been published; that is a long while ago?—I have a kind of recollection that a long while ago one of the French chemists found that oxygen did go in the case of preserved meat; meat which had been sterilised by heat very slowly absorbed oxygen.

24711. Any experiments I saw on the subject had the result arrived at by you and myself, that there was no change, at least no appreciable change?—I daresay that after a long time there might have been very slow oxidation.

24712. (*Sir William Ramsay.*) Anyhow it appears to be mostly a biological process, and when life is excluded the absorption of oxygen is either nil or excessively slow?—Quite so. Here of course the question that I was rather anxious to decide was whether the action was enzymic action, *i.e.*, purely enzymic, or whether it was chemical or biological, and I think the experiment we made on that point was convincing; we did not repeat it, as it appeared unnecessary to do so.

24713. It appears to be so. In section C you deal with the experiments made with cultures of the same organisms and nitrated broth, and although they are not as yet completed, the results so far obtained show that bacillus coli communis liberates nitrogen from a nitrate in broth culture; bacillus lactis ærogenes does not do so?—Our preliminary experiments seem to indicate that; I have never had time to follow that matter out as I should have liked to have done.

24714. Perhaps Dr. Houston could give us some information on the point. *Dr. Houston*: It has been stated that a large number of these coli organisms do produce minute traces, but I do not think more than that. While I am on that, might I ask Dr. Letts about the nitrate question; when did you test as a rule for the evidence of the presence of nitrite?—At the end of 24 hours.

24715. As soon as that?—Yes.

24716. I was wondering whether possibly the test had been made after the second process had taken effect, because the nitrite is formed very rapidly as a rule with a 10 per cent. broth, containing ·1 per cent. of nitrate; the great majority of sewage organisms produced abundant nitrite in 24 hours at blood heat. The exception is chiefly as regards organisms like the streptococci. I have tested 300 or 400 of these, and I have never found one that reduced nitrate to nitrite, but all the varieties of bacillus coli that I have tested reduced it vigorously?—You will come presently in the continuation of my evidence to cases in which when the nitrate has been produced naturally and is in smaller quantities than in these first experiments conducted with added nitrate, that nitrites are generally formed. It is rather a singular thing that when we added potassium nitrate to the sewage so that the mixture was fairly strong as regards nitrates, as a rule we got no nitrite; all the nitrate seemed to go straight away into nitrogen, with nearly equivalent production of carbonic anhydride, but when our experiments were conducted with mixtures of septic tank effluent and an effluent containing nitrates produced during treatment, nitrites were frequently formed. There was, however, this difference as a rule in the two sets of experiments, that whereas in the first the added nitrate was in large proportion, in the second it was much smaller.

24717. (*Sir William Ramsay.*) It is a question of proportion then, I suppose?—Very possibly, but as yet I cannot say that I have quite got at the explanation.

24718. Of course there could be no difference between artificial nitrate and natural nitrate?—No; the only difference in the conditions was that in the first case there was, so to speak, a large mass of putrefying matter, relatively to the nitrate present, because in a nitrated effluent you have got one of course, which has got over the first rush of fermentation.

24719. Yes, that is so?—Whether that is the explanation or not I do not know, but I was myself struck with the absence of nitrites, because I think that Prof. Percy Frankland some years ago made a number of experiments with a variety of organisms, and he found that a considerable percentage of them gave nitrites; but he seems to have missed the evolution of nitrogen. I may perhaps mention that in the bacteriological laboratory at Queen's College, Belfast, just now, attempts are being made to isolate the organisms from sewage which specially reduce nitrates to nitrogen gas. Of course organisms have been obtained already having this function, but I do not think directly from sewage. They are attempting in our bacteriological laboratory to isolate the specific organisms which reduce nitrates to nitrogen gas, and to identify them if possible.*

24720. What food do they give these organisms—broth?—I think they are using broth.

24721. And adding artificial nitrate?—And adding artificial nitrate.

24722. And aerating, I suppose, with oxygen alone, or must it be anærobic?—Well, I am in doubt about that; though I rather think that the nitrate does not go before all the oxygen has disappeared.

24723. (*Dr. McGowan.*) We have made some experiments on that point, and although we could not draw an absolutely hard and fast line, since the results of the experiments were not quite sharp, I have no doubt in my own mind that the oxygen goes first?—That the oxygen goes first.

24724. (*Sir William Ramsay.*) Entirely.

24725. (*Dr. McGowan.*) I should say entirely. If you are dealing with a clear liquid, apart from suspended organic matter?—In that connection may I draw your attention to Section A, Tables 1 & 2, again, where we tried an experiment of that kind which was rather curious. We aerated one sample of nitrated septic tank effluent, and we did not ærate the other. We got theoretical evolution of nitrogen in both cases; but as might be expected we got more carbonic anhydride in the ærated sample than from the non-ærated sample, so that at first glance that would look as if æration does not affect the question. But then I think that the

*Dr. Carnwath, who has been conducting these experiments, has furnished me with the following particulars:

Working on independent lines, he first confirmed my results as regards (1) the disappearance of nitrates when a nitrated effluent is mixed with a septic tank effluent, and (2) that this action is due to micro-organisms and not to direct enzymic or chemical action. Next he sought to isolate the particular organisms concerned in the process from a septic tank effluent, and by using media containing a diluted peptone broth, and either potassium nitrate or sodium nitrite, he succeeded in isolating two species, both of which are bacilli, but their identification with known species has not as yet been accomplished. Both of these organisms have the power of reducing nitrates to nitrites and eventually the nitrite to nitrogen gas. On keeping they lose power as regards *rapid* reduction of nitrite to nitrogen, but retain their power of rapidly reducing nitrate to nitrite. By making fresh subcultures from day to day they soon regain their power of rapidly reducing nitrites to nitrogen and with very active cultures obtained in this way, complete reduction of nitrate to nitrogen has been observed in a nitrated peptone broth containing about 2 parts of nitric nitrogen per 100,000 of fluid *in less than six hours.*

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apparent anomaly can be explained because the oxygen may have all gone first; and it is possible that only after the liquid had become anærobic the nitrate decomposed.

24726. (*Sir William Ramsay.*) That is a very doubtful question, as to whether the oxygen is entirely consumed before the nitrates are drawn on, and it might turn out to be of considerable practical importance?—May I anticipate a little bit the evidence, and ask you to turn to 24656. There experiments are described, on the changes which occur in the nitrated effluents when they are kept simply in closed and full bottles. From time to time we examined the liquid more especially as regards the dissolved gases. You will find in these experiments that the dissolved oxygen went long before the nitrate was touched; in fact, the nitrate seemed to increase, I presume, from the continued action of nitrifying organisms so long as oxygen was present.

24727. Yes, that appears to be so; it increased from 1·98 to 2·1?—Yes, and it is only some time afterwards that the nitrate begins to disappear, although you will see that the evolution of nitrogen which, of course is a more sensitive and more delicate test than the test for nitrate—the evolution of nitrogen seems to have commenced, well, as early as the 9th day, at all events. The same kind of thing appears to hold with the other experiments; and there again I draw your attention to the very minute quantities of nitrites.

24728. Very minute indeed, yes?—And they were examined with great care from time to time.

24729. They might, however, have been destroyed before the five days elapsed in the nitrites?—They might.

24730. They might have been destroyed at an earlier stage; and yet after all the evolution of nitrogen appears to take place between the fifth and the ninth day?—Yes.

24731. To begin?—Yes; still, I am still in doubt about the question of nitrites; I do not understand when they are formed and when they are not; I mean to say, the exact conditions.

24732. (*Dr. Houston.*) Might I suggest a point there: do you not think that the reason the nitrates were not reduced to nitrites in this Table, Professor Letts, was really that there was not enough pabulum?—Do you mean in the first experiments, Tables 1 and 2.

24733. This one in 24656 that you have just been quoting?—Oh, yes.

24734. You say there were only traces?—There of course the pabulum was very slight.

24735. If you had added sterile peptone, I think it probable that the nitrate would rapidly have been reduced?—Yes, I think it is very possible.

24736. It is the absence of pabulum?—Then, on the other hand, that is the point that I was trying to draw attention to, though you have expressed it in a much simpler way than I have in the first experiments, Table 1, Question 24654; there was plenty of pabulum there; because it was the septic tank effluent to which concentrated nitrate was added; would there not be plenty of pabulum then?

24737. Yes, there would be plenty of pabulum then, in a sense; but it would be partly exhausted pabulum with a septic effluent, that is to say there would be substances present which might inhibit the bacteria from exercising their functions; it is not in a very suitable form; it is pabulum, but not in a very assimilable form to bacteria?—Well, nevertheless, the reduction of nitrate to nitrogen gas occurred rapidly and fairly completely.

24738. That is so.

24739. (*Sir William Ramsay*) The table in 24656 also is an effluent there, a treatment of a septic effluent?—Yes, but that is after it has been sprinkled.

24740. After it has been sprinkled; after it has been oxidised?—After it has been well oxidised.

24741. I should like to ask as regards the answer to Question 24654, below the second table, Section C, the words occur, "It is somewhat difficult to find an explanation for the incomplete reduction of nitrates in all the experiments of the second and in some experiments of the first series contrasted with the complete reduction which occurred in the experiments already described in which potassium nitrate was added (in concentrated solution) to the septic tank effluent." Was there air present in the second experiments?—To start with, yes.

24742. Which very soon became exhausted, I presume?—Yes, no doubt. I am afraid that I have used the words "anærobic" and "ærobic" rather loosely there.

24743. I see; I just wanted to know?—It was not anærobic to start with, but it soon became anærobic.

24744. It soon became anærobic?—It was merely to distinguish the aerated from the non-aerated.

24745. Further on you speak about "a certain volume of septic tank effluent passed through the sprinkler and its bed, and thence made its way into the mixing tank while (in the first experiments) the same volume of untreated septic effluent also passed into the latter," the object being to produce an ærobic and an anærobic liquid. The septic tank effluent, I presume, before it has been sprinkled may be regarded as anærobic mixture?—Yes.

24746. Then after sprinkling it is an aerobic mixture?—Yes.

24747. That is practically the process you propose to apply to Belfast?—Well, I am trying so many experiments in attempting to solve the Belfast problem that this is only one string to my bow.

24748. But as I understand it rightly, you propose to have a mixture of an anaerobic and an aerobic liquid, and then by their mutual contact nitrogen would be evolved; but the total amount of nitrogen would be very much reduced in the final effluent?—That is the point, you see, these nitrates encourage the growth of the seaweeds which we suffer from so much; but on the other hand the object of most methods of sewage treatment is to foster or encourage the production of nitrates, so a totally different system is necessary for Belfast than for most other places; therefore one of my main objects is to get rid of the nitrates as much as possible, and these experiments here have been made largely with that object.

24749. And you think this is a practical method of reducing both the albuminoid ammonia and the nitrates by getting them to give free nitrogen?—As I have pointed out later on, it is easy to reduce the nitrates, but to do that and also get very good purification, seems to be hard; and I have not gone far enough as yet; but if you will look at the diagram (on page) you will see how very striking is the reduction of nitrates on the third column.

24750. (*Colonel Harding.*) It is at the expense of the production of more free ammonia?—Not producing, I think, but not getting rid of as much free ammonia.

24751. If you have less nitrate you have more free ammonia left, according to this diagram which you place before us?—Yes, we have not got rid of the free ammonia to such an extent as I should like to see.

24752. Does not the ulva take up the ammonia more freely than the nitrate does?—Yes.

24753. Therefore is it not a disadvantage?—Well, as I say, the experiment——

24754. If that reduction of nitrates involves a larger quantity of free ammonia?—Yes, without doubt the getting rid of the free ammonia is the main thing; and I think it would be possible to modify this process so that more free ammonia would be got rid of as well as the nitrates; I hope that, at least.

24755. (*Sir William Ramsay.*) Taking the second column, No. 3, of this diagram, and adding together the top space and the bottom space, you will see that the bottom space, what is called "free ammonia," there is pretty nearly equal in area to free nitrogen, and you have therefore a space pretty nearly equal to that in which the word "nitrate" is printed, and free nitrogen which is available nitrogen for the use of the ulva; and in the third column you have only the bottom part free ammonia and albuminoid ammonia as available food; there is a very much larger space filled up by free nitrogen, so that on the whole the sustenance is not so great.

24756. (*Colonel Harding.*) The point I had noticed was that Dr. Letts had said the ulva takes up the free ammonia much more readily than the nitrate; but it

is bad, so it is a very interesting biological fact that I think there is no doubt about it.

24757. (*Sir William Ramsay.*) I think this is an opportunity for putting the general question; you were thinking of purifying the Belfast sewage by putting a bed of ulva through which the sewage or partly purified sewage should run, and you talked of trenching that bed occasionally and using it?—Yes.

24758. Has that scheme entirely fallen through?—No, we are still at work upon it; though owing to structural alterations in the works last year I was not able to continue the experiments; but we had the necessary tanks made for the experiments; and I think I pointed out to the Commission when in Belfast—I am not quite certain that I did—that nature had performed the experiment for us pretty largely; because since we got the tanks there the sea-weed appeared spontaneously in them, the germs of the weed having evidently accidentally gained their way into the sewage from the river; then when they got into the tanks they germinated, so that, without putting any seaweed into the tanks, we had a crop appear spontaneously.

24759. Then what sort of effluent do you get from the tank?—Oh, it was an excellent one.

24760. Very little nitrogenous matter of any kind?—I have not as yet examined it chemically; I am speaking of its appearance. I had to wait until the necessary structural improvements had been made so as to make the tanks suitable, and that has compelled me to wait until this summer to experiment on a practical scale (in contradistinction to mere laboratory experiments, which were completely successful) as to the purifying effects of the sea-weeds in removing whatever ammonia remains in the effluent after septic tank and double contact bed treatment, for it was in the tank into which this effluent passed that one of the green seaweeds appeared, but it dies down during the winter.

24761. I thought it was to be attempted on a very much larger scale by staking in a large part of the foreshore?—Well, we thought it best to make tentative experiments first of all, but that is the idea if these succeed.

24762. Is the prosecution of the ordinary method of purification, which consists in the use of contact beds, not being taken as the main plan; is not the building of contact beds going forward at a great rate?—No, further construction is at present impossible as all the available space has been used up. At present the sewage of only about 50,000 out of a population of over 300,000 is being treated, but from 70 to 80 acres of land are being rapidly reclaimed from the foreshore, and until that is done no more tanks or beds can be constructed.

24763. If your plan were to come in, would it be worth while reclaiming those 70–80 acres; would you not be able to make use of the foreshore, which is occasionally covered with water, as a bed for your ulva?—Oh, I think we shall still do that, apart altogether from the reclaimed ground; the reclaimed ground is only for the purifying plant.

24764. Would it be necessary to have such purifying plant if you manage to get a large bed of ulva?—Well, we think it will; you see a Bill has been passed requiring purification; I do not know if the Local Government Board would pass a scheme of purification only by seaweed, because it would not get rid of the solids.

24765. Would it not? There would be very considerable filtration through the seaweed?—Well, I should be rather afraid that the solids would trouble us very much, and I think that the Harbour Commissioners would object to any scheme which did not remove the bulk of the solids.

24766. You do not propose to treat the sewage in any way before running it into the bed of seaweed, would you?—Oh, yes.

24767. You would always?—Yes, to get rid of the bulk of the ammonia as well as the suspended solids.

24768. Screening it? But in this particular case is it not your object to feed the seaweed with all the ammonia you can give it. You wish a luxuriant crop of seaweed, do you not, in that particular fenced-in place?—We have a tremendous lot of it in the Lough; our object is to reduce it there to the minimum.

24769. To confine it, dam it, let all your sewage into a park of the seaweed?—No, only the effluent—in order to clear out the last traces of ammonia, and if possible of the nitrate also, thus depriving the effluent of its fertilising properties in relation to sea-weeds when it escapes into the Lough.

24770. Have you ever thought of admitting the crude sewage into the seaweed?—Oh yes, we have.

24771. What is the objection to it?—The solids would be the main objection.

24772. (*Colonel Harding.*) Would there be no dissolution of the solids?—There might be, but you would still have inorganic solids troubling you, and I think that the Harbour Commissioners would object to that.

24773. In so far as they were inorganic, would they be objectionable on the sea-shore?—They would have to dredge them from the channel.

24774. Would the volume of them be sufficiently important to necessitate that?—I think so.

24775. Could they not be got rid of by catch pits?—The detritus would, of course, the road detritus, but I think there is a lot of fine matter that would not.

24776. (*Mr. Stafford.*) Would not your marine garden be rather a foul smelling thing?—Oh, no, not if it were looked after.

24777. (*Sir William Ramsay.*) So long as it is growing there is no smell at all?—No.

24778. (*Mr. Stafford.*) What are you to do with the seaweed?—There are a great many things we can do with it; we can burn it, we can dig it into the land; there is plenty of land to work it; a third thing would be to distil it into ammonia.

24779. (*Sir William Ramsay.*) Dry it and distil it?—Yes.

24780. (*Mr. Stafford.*) You might do all these things or deposit it on the shore?—There is the difficulty of collecting it; it is spread over such a wide area, collecting is very troublesome.

24781. (*Sir William Ramsay.*) It is at present collected?—Oh, yes, a lot.

24782. (*Mr. Stafford.*) The cost of collection was only estimated, I understood, at £1,000 a year, an outside figure?—I fancy it would be more than that.

24783. The estimate given at our inquiry is £1,000 a year?—Only £1,000?*

24784. £1,000. We have given you up to a larger limit?—Yes.

24785. (*Colonel Harding.*) There would be this difference that in a controlled area you would be collecting the *ulva* in a living state, whereas in the other case you are collecting it in a decaying state?—That is so at times at least.

24786. In a putrefying condition?—Very often.

24787. (*Mr. Stafford.*) Hardly in a putrefying condition; then is on the foreshore?—Yes, if not removed quickly as is too often the case. It is only after a strong wind blowing shorewards, that the seaweed is washed up in manageable quantities, so that the men employed for the purpose can easily fill their carts; at other times it lies about in such thin layers that it cannot be easily collected.

24788. And then it does not make a nuisance?—It begins to make a nuisance very soon then in warm weather, and the nuisance often becomes acute.

24789. (*Sir William Ramsay.*) The process of collecting is not a very perfect one until it is blown up by the storm?—Yes.

24790. Let it come ashore and collect it rather than attempt to purify the sewage by means of ulva. It is a mere question of cost, but if the collection is imperfect the amount that remains would still make a nuisance?—A great deal of it is deposited perhaps a little way from

* Since giving this evidence a Provisional Order of the (Irish) Local Government Board has passed through Parliament and has received the Royal assent whereby a new Authority or Joint Board has been created which has power to raise and expend a sum of £2,000 annually in keeping the foreshores of Belfast Lough clean.

the shore on some of the sandbanks; I am not at all sure that carts could get out to that distance.

24791. It makes a nuisance even there; it decays?—Well, it grows there and then suddenly a wind may come and we may have it in, perhaps, hundreds or thousands of tons; we cannot clear it away entirely; a nuisance bursts out.

24792. It would mean spasmodic work on the part of the workman I suppose?—Yes, I think so.

24793. Not regular work?—Not regular work. Perhaps I may take this opportunity of saying I am trying various things to prevent the growth of these seaweeds, and the latest is one to which perhaps the attention of the Commission has been directed—that is the effect of sulphate of copper—I understand that they have been doing that in the lakes in the London parks, I do not know if it is true, but I have read it I think in the *Graphic* or somewhere, that in order to eradicate the green filamentous growths which often appear in such quantities in fresh water ponds or lakes, a very small dose of sulphate of copper is added to the water. The discovery of this toxic action of minute quantities of sulphate of copper on *algæ* was made, I believe, in America, and if I am correct in my information, it is now being applied as I have mentioned in London. I have tried a few experiments myself, and there can be no question that one part in 100,000 of water of solid sulphate of copper does eventually destroy the green seaweed; and it has been proposed to try that experiment all over the lough. But I am a little bit disappointed in some experiments which I have made in a pond which I have at home, which show that whereas the sulphate of copper kills the green fresh water *algæ* very rapidly at first, you have to go on adding it; the weed springs up again.

24794. Does the weed get used to the sulphate of copper?—I think not, but after the sulphate of copper has disappeared with the current the effect stops; then you have to add more.

24795. The spores of the weed are not killed?—They either are not killed or more appear.

24796. But would it not be quite an impracticable scheme to add sulphate of copper to the waters of Belfast Lough in sufficient quantity?—Well, I am afraid of it, I think the cost would be prohibitive myself. Perhaps it might not be prohibitive if one or two doses would do say, for a couple of years, but if it has to be done several times in a year, I am afraid it would.

24797. It would surely be very expensive. Then we may take it, I fancy, that up till now you have been making experiments on the cultivation of ulva with the object of passing some purified sewage through it, but the large scale experiment has not come off?—That is so.

24798. But you hope to carry out a large scale experiment as soon as there is land to put it on?—I hope to do that and in the meantime this destruction of the nitrate in the purified effluent is another point that I am aiming at, and a third was this action of sulphate of copper, which I fear must be abandoned owing to prohibitive cost.

24799. May I just refer to one point again; I do not think I am quite clear upon it; you do not regard it as a good thing to feed the ulva with the best nutriment which you can get, with the object of making a large crop and so removing it, and so as it were making ammonia out of it?—I think if we were in Germany and could start a chemical factory for ammonia that would be an excellent thing, but I am not quite certain that I could persuade the Belfast people to do anything so practical, although they are starting factories up there in the north now for obtaining ammonia from peat, at least I see that advertised, and I think this would be, in fact I know it would be, a much more prolific source of ammonia.

24800. Oh, much more prolific?—I would like to draw your attention, however, to the latter part of 24654 again, because the point to my mind which is interesting and important is the extraordinary rapidity with which these nitrates are destroyed.

24801-2. Would you refer us to the table?—The last Table in 24654, p. 597. You will see that, after three hours lingering in what I call the denitrifying beds, the whole of the nitrate goes.

24803. That is true?—So that in some way the denitrification is hurried up in the most extraordinary manner.

24804. The temperature is low, judging by the time of the year?—Yes, the temperature is low. I took the temperatures, but I have not put them in the table.

24805. In 24656 you speak of the first change of any importance being the disappearance of the dissolved oxygen which occurs with relative rapidity and was complete in four or five days. That is a very different time from the change you have just been alluding to. It takes a considerable time for the dissolved oxygen to appear in an anærobic fermentation?—Yes, but in those experiments a nitrated effluent was merely left to itself in a closed vessel. There was no contact bed there.

24806. Yes, I see, the nitrated effluent from the sprinkler was simply left to itself in a full stoppered bottle?—Exactly, and the point which so much impresses me is that when this same effluent was mixed with the effluent from a septic tank, and the mixture passed into a contact [or, as I have there called it, a denitrifying bed], denitrification occurred so rapidly. The first experiment, as I have stated, was made before the bed had got into working order. It was a new bed, therefore; you will see that the nitrates have not gone, but in all the other experiments with the exception of the last the whole of the nitrates went. In the last experiment there was a very much larger proportion of nitrate in the sprinkler effluent than in any of the rest, and in that case a little remains, but only a very little in the final effluent.

24807. (*Colonel Harding.*) Why we like to see nitrates in an effluent is because we know they will assist the oxidation of the remaining organic matter?—Yes. As against that you have the first Table in 24656, to show the actual rate at which that occurs in a nitrated effluent. Then the change is exceedingly slow, as Sir William Ramsay has pointed out. There again I take it that Dr. Houston would say that it was want of pabulum in all probability.

24808. (*Dr. Houston.*) I should think so.

24809. (*Sir William Ramsay.*) You go on to speak of the method of estimating oxygen, but that comes subsequently?—Perhaps you will allow me to say that I thought those experiments on the changes which occur in the nitrated effluent, when merely kept, were of importance because, in many of the large manufacturing towns, the small watercourses often consist largely of sewage effluent and nothing else, and I was anxious to settle definitely the question so far as I could as to whether under those conditions, where perhaps two or three days are necessary before an effluent makes its way out to sea, that it would remain perfectly sweet and free from nuisance, and I think from the very slow rate at which the nitrates go that the question is settled.

24810. That the presence of nitrates in a stream tends to interfere with the putrefaction of a stream, at all events the rapid putrefaction of a stream?—That is so.

24811. Yes, that is an important point?—Of course, I pointed out that laboratory experiments do not actually reproduce the actual conditions, as ordinary laboratory conditions are, so to speak, static, and ignore the effects of flow and so on.

24812. If flow takes place you cannot eliminate the presence of free oxygen?—No.

24813. Then you regard it as the case that the disappearance of sewage matter during the flow of a stream is not largely due to the nitrates contained in that stream, but chiefly to the action of the free oxygen?—I fancy that the free oxygen is a very much more important factor than the nitrate. The nitrate is a kind of last resource.

24814. You use limestone for your beds at Belfast?—We have experimented with it as you will see in 24682, The limestone seems to give a fairly satisfactory results but it is rather curious that the different materials tried seem to act very differently. It was rather unexpected to me in the experiments we have made—and they are pretty extended now—that broken brick fragments are much the best.

24815. So I see. What is the most easily obtained substance ?—It is very difficult to get the broken brick.

24816. The whinstone and limestone are common in Belfast ?—The limestone would be the easiest and the cheapest to get.

24817. Would it not easily dissolve away or is the solvent action of the carbonic acid so slight as to be inappreciable ?—That is a very interesting point that I think it would be well worth following up ; I have never tried it. A sewage effluent is highly charged as a rule with carbonic acid.

24818. I should have thought it would dissolve away, but it may not do so, at a sufficient rate to make it worth while troubling about ?—It would be well worth trying, I think.

24819. How many analyses are represented in the table in 24682 ?—Not so many as I should wish. I think a maximum of about six series.

24820. That is to say six of each ?—Yes, but there again they were not all alike, because after we had got bad results with the whinstone, we emptied those beds out and put in clinker and coke, so that you may say with clinker and coke there are only two or three experiments. I have drawn attention to that, I think.

24821. Yes, I think you have. How long were the experiments continued ? I do not think you have mentioned that ?—Well, they really are still being continued.

24822. But how long was one bed kept running before you began to make experiments upon it ?—Oh, three or four months.

24823. Then you had a number of beds filled side by side ?—Filled side by side.

24824. Each filled with the same sewage ?—Yes. We thought that was the only satisfactory way to work. I think in some places they have first of all experimented with one material and then afterwards with another, ignoring the fact that the composition of the sewage may in the meantime have changed.

24825. And the temperature ?—The only fair way of comparing them is to work them together.

24826. (*Dr. McGowan.*) At York there is a filter with four segments of four different materials fed by the same sprinkler, and we have made observations on that ; the segments are not all of equal size.

24827. (*Sir William Ramsay.*) Is it continuous filtration ?

24828. (*Dr. McGowan.*) It is continuous filtration of a septic tank liquor ?—I do not know if I have a right to ask a question ; it interests me very much what Dr. McGowan says ; I have heard of the York experiments, but are my observations on the broken bricks—that they are superior in their action—confirmed ?

24829. (*Dr. McGowan.*) I think, as far as my memory goes, it so happens that the broken bricks at York are the coarsest of the four materials, and the purification results went, you might say, directly as the fineness of the material. The finer the material the better the purification ; that is to say, the longer contact the sprinkled liquid had before it got through.

24830. (*Sir William Ramsay.*) These are experiments with contact beds ; York experience was with sprinkler beds.

24831. (*Dr. McGowan.*) With sprinkler beds ?—In that connection perhaps I may draw your attention to our experiments with limestone. We have tried the effect not only with different materials but with varying fragments, and the results rather surprise me. We have got better purification, so far as the oxygen absorbed test and the albumenoid ammonia are concerned, with the coarse and medium fragments than with the fine, but we have got more nitrates produced with the medium and fine. I was very much surprised at those results.

24832. (*Sir William Ramsay.*) I think we might very well ask Mr. Frye a question here, because he has given information as regards the effect of putting different materials through the same mesh. Would you mind just explaining that to the Commission ?

24833. (*Mr. Frye.*) In York for the segmented filter we tried to obtain materials of exactly the same size, and we broke the materials to the same mesh, but we did not obtain the same size in the material ; broken brick was bigger in size than coke or clinker.

24834. (*Sir William Ramsay.*) Owing to the different size into which the materials broke.

24835. (*Mr. Frye.*) Owing to the different size into which the materials broke ?—It is very interesting, because that would be the opposite to what Dr. McGowan said, and the brick may yet turn out to be the best material.

24836. (*Dr. McGowan.*) The brick gives the worst effluent, the coarser the material the worse the effluent ?—That is what I say, but then, I got a better result with the brick.

24837. (*Sir William Ramsay.*) Yes, that is so. Do you notice any difference in the appearance of the material which is being used for those contact beds ; does the slime appear to adhere to any one better than another ?—No, I have not made any observation on that point.

24838. It occurred to me possibly an alkaline material like limestone might give a better holding ground for the slimy matter which accumulates in a bed ?—I fancy the limestone might give a better result from the ordinary point of view for another reason, viz., that nitrification might occur more readily in the presence of a bed of that material owing to its being alkaline in character.

24839. Those comparative experiments are very interesting. Can you throw any light upon the relative ease of purification of clarified sewage and septic tank liquor in the contact beds. In question 24688 you say that you have made no direct experiments with the continuous filter, but you speak of the relative ease of purification of the clarified sewage and septic tank liquor on contact beds ?—The readiness with which it nitrifies is very striking.

24840. The readiness with which it nitrifies is very remarkable, is it not?—I cannot explain that at all at present but when we work, as you will see from the diagram, with contact beds only, we get an actual reduction of nitrates, but as soon as we introduce the septic tank we get a very fair production of nitrates. I do not know if I am right at all, but it seems to me as if there was some change, whether biological or chemical I do not know, perhaps hydrolytic.

24841. In the septic tank ?—In the septic tank, to fit it for nitrification or prepare it for nitrification.

24842. I do not think the method which you adopt for estimating oxygen is one which has been tried in my laboratory or in Dr. McGowan's.

24843. (*Dr. McGowan.*) No, we have not tried it.

24844. (*Sir William Ramsay.*) We have tried it and we found it was extremely easily worked and we got good results from it ?—Perhaps I might call your attention in connection with that to the appendix to my evidence (page 612), in which the results of some recent experiments are described where the method seemed to break down. It was singular that after we had done a very large number of experiments and a lot of work in which we had always got singularly accurate results, at last we ran across a class of liquids in which the method did not seem to work properly, and it is peculiar and interesting. Apparently there is some substance formed when a nitrated effluent is kept which acts as an oxydising agent and behaves like free oxygen, so that you actually find oxygen in a liquid of the kind by the volumetric process when there is none there.

24845. That is very interesting, but have you tried any other process on it ?—Yes.

24846. How did you know there was no free oxygen there ; by boiling out the dissolved gases ?—If you look at the table at the last page of the appendix you will see the results there in the fourth column, on the determinations by gasometric analysis. Then in the first, or rather the second column, you will see the results of the ordinary volumetric process and in the other columns on the right-hand side you will see the results which we got by employing a preliminary method of treatment to obviate the inaccuracy. Two ideas suggested themselves ; one was to get rid of this intermediate product by oxidation, to convert it into a more stable body ; the other was to reduce it with the same object and, as far as we could find out, by oxidising it as a preliminary treatment with acid permanganate it did pass into a more stable body,

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which did not act in the same way that free oxygen did.

24847. Yes I see ; that is very curious ?—For instance, if you compare the experiments in series C, where the correction has been made, and where it has not been made, you will see that the correction is fairly good ; sufficient for practical purposes.

24848. You have no idea what sort of substance acts like free oxygen ?—No ; I think it is very interesting though, to follow it up if possible. I have suggested it is a body of a nitro or nitroso nature.

24849. It looks like that.

24850. (*Colonel Harding.*) I have very little indeed to ask Professor Letts. I would like to ask him as regards his marine sewage farm, if he has any estimation as to the extent to which marine ulva takes up nitrogen from sewage. Suppose, for instance, you had 100 cubic yards of sea water with a thriving growth of ulva, at what rate could you pass sewage through it so as to obtain purification of the volume passed ?—I have made experiments upon that point, sir, and speaking from recollection now if you have a fair quantity of ammonia in sea water it is practically all removed in five hours ; over 90 per cent. is removed in five hours.

24851. Removed from what volume. What I wanted to get at was the effectiveness of the ulva as a purifier of sewage ?—From any volume provided there is sufficient *ulva*, but there must be a certain area of sea-weed surface for a given volume of polluted sea water. Then the ammonia is practically all removed in five hours.

24852. You are unable to say, given a certain area of sea water and sufficient growth of ulva, what quantity of sewage could be passed through that area so as to obtain purification of it ?—I think that I have the necessary data, because in the experiments on the subject we determined the area of the weed, and then afterwards we weighed a set of square inches so that we determined the surface corresponding with a definite weight of the sea-weed, and that I think would enable me to answer the question if I had access to my notes on the subject.

24853. Do you happen to know of any fresh-water weed which in the same way will take up ammonia from sewage at a sufficient rate to warrant its being used in that way as a purifier ?—I tried some experiments upon one water weed which unfortunately I did not get identified botanically. It was a filamentous weed grown in a pond I had and it seemed to act quite as well as the ulva ; it absorbed the ammonia readily.

24854. That would be exceedingly interesting, if we found any vegetable growth which took up the ammonia at a sufficient rate to warrant its being used for the purpose of purification. We do find in fact that these growths arise in the channels which carry away effluents but the importance of them as purifiers has not yet been gauged so far as I know ?—Your question reminds me of some experiments which I made some little time ago, which seemed to supply an ideal method for sewage treatment whereby sewage is converted into free oxygen. It sounds very remarkable but the experiment consists merely in keeping ordinary sewage in a closed bottle, when, after some time, you get green growths appearing ; those green growths then act upon the carbonic anhydride, free oxygen is evolved, and eventually all the carbonic anhydride is thus acted upon.

24855. (*Sir William Ramsay.*) And the carbon comes into the growth ?—Yes, and probably the nitrogen also. Thus finally the sewage is resolved into vegetation and oxygen. If this could only be carried out practicably it would be an ideal method of sewage treatment as a fully oxygenated and perfectly pure effluent results.

24856. (*Colonel Harding.*) Do you not think that point is one well worth investigating ?—Oh. I do indeed.

24857. In fact that the whole question of growth in connection with sewage is one of which we know comparatively little ?—It is a most important one.

24858. Every liquid of greater or less impurity passing through the channels seems to register its condition on the walls of the channel ; in some cases grey growths, in other cases green growths, in other cases you are liable to get more highly organised plants ?—That is so.

24859. And the utility of these growths as a means of purification does not seem to have been so far investigated ?—No, and I think it is a most important thing.

24860. It occurred to me that as you were on that subject, proposing actually to use a marine weed for the purpose of purification, it might have led you to give attention to this very interesting investigation ?—No ; I am obliged to you for your suggestion, it is one which has occurred to me, but unfortunately I have no assistant practically to help me, so every moment of my time is taken up. If I only had an assistant or two I would turn one of them, or perhaps several of them, on to investigations on that very question.

24861. (*Mr. Stafford.*) I do not know whether you mentioned what the system of treatment of sewage in Belfast is at present ?—Of course a number of experiments are going on ; we are experimenting with septic tanks, with contact beds, with continuous filters, and as I have explained on other lines also, to get rid of nitrates.

24862. But you are treating about one-sixth of your sewage ?—Yes, merely by contact beds.

24863. By tank treatment and contact ?—Well, I do not think you can say it is tank treatment. It is accidently and incidentally tank treatment because all the sewage as you know in Belfast is received into an underground tank and is allowed to stay there between the times of high and low water; then afterwards it is run into the Lough, but I do not know if you call that tank treatment.

24864. It is retained as a matter of fact ?—It is retained as a matter of fact and the coarse solids are separated ; about one-sixth of the sewage thus screened and settled is run on to contact beds.

24865. That is your system of purification so far as it has gone ?—So far as it has gone.

24866. What do you propose to do ; have you yet decided ?—No, but I think from all the experiments we have made that septic tank treatment will be part of it.

24867. You probably will follow on the same lines ?—I do not know. Our surveyor, I think, is very much in favour of these continuous or sprinkling filters, and, although they produce so much nitrates, yet if I succeed in eliminating nitrates he would much prefer them because he would reduce the area of his works.

24868. You do not want nitrates ?—I do not want nitrates.

24869. And nothing has been decided yet ?—Nothing has been decided and of course there is no immediate necessity because I understand these 70-80 acres of ground cannot be reclaimed and brought into use for about two and-a-half years. They are pushing on the work itself, but it is a large undertaking, so that until that reclamation is done there is no necessity for finishing the experiments.

24870. So you have got about two and-a-half years for experiment ?—So I understand. I am anxious to get my experiments concluded as soon as possible.

24871. What is your experience of the efficiency of the removal of all that ulva now by carting ; that has been in operation, has it not, for the last two years ?—It has, and my experience is that it is a very expensive process and that the people have not arrived at the most economic way of doing it.

24872. Surely it is not an expensive process ; it is only £300 a year ?—Well, they pay the farmers 1s. a ton to take it away and the farmers ought to be paying them 1s. a ton for being allowed to take it away.

24873. What is the expense ?—At present we have only had control of £500.

24874. That is not a very expensive method of dealing with a nuisance and the sewage of Belfast ?—Yes, but unfortunately it has not dealt with it ; it has only dealt with a portion of it.

24875. That is what I want to know ; what is it ?—My experience is that it has ameliorated, but it has by no means cured the nuisance.

24876. And you do not think you would have cured it if you had pushed it to its full extent and removed all the ulva as it deposited ?—I think if I remember right Colonel Harding asked that very question when he was

in Belfast as to what the cost of the carting would be, and the then City surveyor, Mr. Bretland, according to my recollection, was very cautious about giving him an answer. I think it is perfectly possible that it might cost less to remove the seaweed than to treat the sewage. Am I right in believing that is what is in your mind?

24877. That is what is in my mind?—I think it is possible.

24878. I presume the removal of the seaweed after all would not deal with the whole problem.—No, because I am under the impression then that the Harbour Commissioners would step in and say, "But this does not get rid of the sludge which you throw in, and which is blocking up our channel."

24879. (*Sir William Ramsay.*) And from the other point of view it would be impossible to deal with the whole of the seaweed; you would deal with the main bulk after it had been thrown up, but the small quantities which lie about could not be dealt with?—I think it would be extremely hard; I do not see any way of dealing with them at present; but a method might be discovered, perhaps.

24880. (*Mr. Stafford.*) You speak about other places you have been to visit and you speak about Dublin Bay; there is not very much nuisance arising is there in Dublin Bay from the deposit of "ulva."?—Well of course I do not live there and you do; so you know more about it than I do, but I have often heard the people complaining.

24881. But was it from the "ulva" or from the sewage discharging within a very short distance indeed from the foreshore?—My authority is Professor Hartley, and he says he has frequently noticed a rather serious nuisance.

24882. From the Liffey or the "ulva"?—From the Liffey; I never have. I have seen the seaweed in fair quantities on the northern side of the estuary but not in the Liffey.

24883. Is it not a fact that the nuisance is greatest in Upper Clontarf where the sewage discharges in front of Clontarf?—Oh, it is the whole way down to Dollymount.

24884. But the place where it discharges most apparently is Upper Clontarf, and there there is very little deposit indeed of seaweed?—Well, I cannot say that I have ever smelt any nuisance from the sewage itself, though I have been down there very often.

24885. You think that what you did smell there, for there is a smell, is from the Liffey?—Well, personally I have not noticed the smell.

24886. You have not noticed the smell?—No; my authority for the nuisance is Professor Hartley. Perhaps I have not been down in the hottest weather, though I have been down in the summer.*

24887. You know the outfall, the Dublin Sewage, at least where it is proposed to be, and the present outfall of Rathmines and Pembroke?—I am very familiar with both of them.

24888. Is there any nuisance arising from the Rathmines and Pembroke discharges?—No, none; it is a remarkable example, I should say, of a very effective method of sewage disposal.

24889. And non-treatment?—And non-treatment of the sewage there. And here the cases of Belfast and Dublin or rather of Belfast and Pembroke and Rathmines are different, because in Belfast the sewage runs into a Lough, which is ten or eleven miles long, so that Belfast, which is at the head of it, is that distance from the open sea. The main tide makes a sweep through the outer half of the Lough, leaving only a very slight current in the upper reaches, so that it is doubtful if the Belfast sewage really gets out of the Lough, and from float experiments I am convinced that it does not do so in one tide. The upper reaches of Belfast Lough are therefore more or less a cesspool, whereas in Pembroke and Rathmines the sewage runs into a relative swift current; and the outfall is really out at sea, a mile out at sea.

24890. But still within the harbour?—The harbour is purely artificial.

24891. It is, yes; it is a containing wall?—I think the effect of the containing wall is really to increase the current, the natural current from the Liffey, so you get the sewage swept right out to sea, and any which remains is completely oxidised. Dr. Adeney has shown that, by analysing the water at all states of the tide and all over Dublin Harbour. I lately have been analysing the sand or mud of its bed, and I find that even close to the outfall of the Pembroke and Rathmines Sewer the amount of sewage sludge calculated on the nitrogen present is not more than from one to two parts per cent. at the mouth of the sewer.

24892. Would you advocate then that the whole of the Dublin sewage should be discharged unpurified at the same place?—Well, perhaps not at the same place, but I think it would be perfectly safe if it were discharged at the mouth of the harbour.

24893. If it goes out at the same place in the same way as this why not discharge it there?—Because you might overburden the water.

24894. If it is always swept out rapidly to sea you will not have much nuisance?—Yes, quite so, but on the other hand, the population of Rathmines is 60,000, while the population of Dublin is 300,000, so you would increase the amount of sewage by five times; I would not like to say off hand that you could do that with impunity.

24895. But you would advocate then the discharge of crude sewage into a tidal river such as you have got at that particular part of Dublin Bay?—I would not call it a tidal river, it is well out into the estuary, if you mean the mouth of the harbour.

24896. I mean where you discharge it at present, the Rathmines and Pembroke discharges?—Well, I can only give you the actual results of our investigations; the discharge is efficient if you examine it from every point of view. From the ordinary point of view there is no nuisance, no sludge banks, nothing visible. From the harbour engineer's point of view, my examination of the bottom shows that there is no appreciable quantity of sewage sludge, so that it seems to me it is absolutely satisfactory, and therefore I should say that if you could take Dublin sewage out to the mouth of the harbour, and discharge it there you would get rid of it perfectly satisfactorily.

24897. Without any form of treatment?—Yes, in my opinion.

24898. Therefore, the expensive treatment which Dublin is going in for at the present moment is, according to your view, unnecessary?—I believe so. Moreover, I fear that you will kill all the fish when you treat the Dublin sewage with lime; it is an archaic process. Now there are salmon running up the estuary, they are being caught there; there are nets at the present moment as you know; and I think it will be very risky to adopt a lime precipitation process, because the Dublin Authorities are going to discharge the effluent at all states of the tide; not as Pembroke and Rathmines do, only on the ebb, but at all states of the tide. I am decidedly of opinion that sometimes the discharge of crude sewage can be made with perfect safety into the sea; at other times I think it can be made only with great danger. It all depends upon the conditions. If you get a fairly rapid tide and deep water you can discharge, in most cases at all events, crude sewage into the sea without any danger at all.

24899. Yes, if you have got both those conditions?—That is my view.

24900. And you discharge upon the ebb tide?—Yes. One of the best places of that kind that I have seen is Portsmouth. The whole sewage of Portsmouth is discharged at the mouth of Langston harbour; there, a rapid tide shoots it right across past the Isle of Wight; and as a consequence no trace of it is left; the sands are white, and as the Solent is, as one might say, the aquatic playground of England, any obvious pollution would certainly be noticed, but I have never heard of

* On reading over the proof of evidence, it seems to me that Dr. Stafford and I were at cross purposes. Everyone knows that the Liffey in Dublin smells very badly at times, but the smell is due to sewage and not to decaying seaweed. The smell, if there is any at Upper Clontarf, is probably due to the same cause, but from the Railway Bridge to Dollymount there is plenty of *ulva* and it must at times give rise to a nuisance.

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any complaints, and it appears to me that Portsmouth is a good example of a case where crude sewage may be discharged directly into the sea with perfect safety.

24901. You have not got much depth of water at that particular portion of Dublin Bay ?—No, but you have got a tremendous scour. The evidence of the harbour engineer is that you have scoured out the bar six or seven feet.

24902. Just another question about Belfast Lough. Do you suppose that the amount of sewage discharged from Holywood and small districts on either side of the Lough would themselves give rise to a sewage nuisance and the growth of ulva if Belfast sewage were treated properly ?—Yes, I am strongly of that opinion.

24903. You think that they would give rise to considerable nuisance ?—I will not say direct nuisance ; I do not say the sewage itself would be a direct nuisance but I do think the ulva would be.

24904. You think there would be sufficient sewage discharge there in fact to keep the ulva nuisance going ?—Yes, I think so.

24905. But not to such an extent as at present ?—Certainly not. My view is that it would be only fair, if Belfast has got its scheme of purification in operation, these outlying districts should also be compelled to adopt some system of purification also.

24906. In fact, you think that there would be a nuisance left there if they do not ?—I think so decidedly.

24907. (*Major General Carey.*) Do you make a distinction between sewage discharged into the open sea and sewage discharged into an estuary or tidal river where it may possibly be returned on the flood tide ?—Decidedly.

24908. You think that they are two distinct cases ?—Yes.

24909. One of which at least may require that the sewage should be treated before discharge. Take the case of the sewage discharged into the estuary, that it should be treated before-hand ?—Quite so.

24910. And I believe you are preparing a report are you not ?—Dr. Adeney and I are preparing a report upon the subject of estuary pollution generally, or rather, I should say, tidal water pollution.

24911. On the pollution of tidal waters ?—Tidal waters generally, yes.

24912. When may we have the pleasure of receiving that report ?—I hope you may have it, sir, without fail in the autumn. The work is growing enormously as the time goes on. I mean to say that we are collecting a mass of detail, so I do not think it will be a very small report when it is finished. There is just one other point to which I should like to direct attention. I do not know, Sir William, whether you have noticed my answer to a question which the Commission has asked about the strength of sewage. I might direct attention to that question (24673). I have drawn attention there to the fact that I think strength of sewage is rather an indefinite sort of thing, and that a sewage may be strong in several different ways. Three of these I have instanced in particular, namely (1) suspended solids ; (2) putrescible organic matter ; (3) free or saline ammonia. I have pointed out that strength in one of these does not necessarily involve strength in several. I have also drawn attention to the fact that the Rivers Pollution Commission appears, as far as I can see, to have given a very high figure for the free ammonia, between two and three times what is found in most large towns. I thought I would just mention that.

Appendix to Mr. Letts' Evidence.

On a simple and accurate volumetric method for estimating the dissolved oxygen in fresh water, sea water, sewage effluents, etc.

By E. A. Letts and R. F. Blake.

The amount of dissolved oxygen which a water contains either originally, or if aerated to start with, which it loses on keeping (but especially the latter), is probably a more important criterion of what may be termed "active" pollution than any other, and the same remark applies also to sewage effluents.

Some years ago we described* a simple, and from the tests then made an apparently reliable and accurate volumetric method, suitable for the determination of dissolved oxygen in all classes of natural waters, and in sewage effluents also, and the good opinion which we then formed of it has since been materially strengthened by further experience.

A large amount of "field" work has been done, and in order to still further test the accuracy of the method a somewhat extensive series of comparative determination has been made in the laboratory, in which the same water sample has been examined volumetrically by one of us and gasometrically by the other. As the significance of the dissolved oxygen in a water or sewage effluent, and the rate and extent of its disappearance when such liquids are kept, is much more generally recognised now than when we first devised the method we venture to bring it under the notice of the Commission, together with the proofs we have obtained from time to time of its accuracy.

Before doing so, however, it may be useful to briefly notice the other volumetric processes which have been employed from time to time for the same purpose. Schutzenberger's method† has received a considerable amount of attention from different observers,‡ and especially from Roscoe and Lunt,§ who introduced an important modification into the process, and compared the results obtained by the method thus modified with those yielded by boiling out the dissolved gases *in vacuo*, and determining the oxygen by gasometric analysis. In all the determinations more oxygen appears to have been found by them by the volumetric than by the gasometric method. In London tap-waters the greatest difference between the two sets of determinations amounted to 0·44 c.c. per litre, and the least to 0·10, and they say :—"The oxygen values obtained by the two methods show close agreement, considering the possible experimental error in so complex a comparison. The mean difference being only 0·28 c.c. of oxygen per litre of water, showing that the method gives good results with ordinary drinking waters."

With Thames water at Richmond the greatest difference was 0·98 c.c. per litre, the least 0·07, and the mean 0·56, while with Thames water opposite the southern sewage out-fall, worse results were obtained, the mean difference being 0·63 c.c.

Thresh's method,‖ in the hands of its inventor, appears to have given exceedingly accurate results. The test experiments were chiefly made with distilled water saturated with air at 10deg., 15deg., 20deg., and

* Proceedings Roy. Dublin Soc., Vol. IX. (N.S.), Part IV., No. 33.

† Compt. Rend 75, p. 875, and Schutzenberger's book on Fermentation in the International Scientific Series [1883], p. 108.

‡ König und Mentschler, Berichte 10 [1877], p. 2071 ; König, Berichte 13 [1880], p. 154 ; Tiemann und Preusse, Berichte 12 [1879], p. 1768 ; Bernthsen, Berichte 13 [1880], p. 2277 ; Duprè, Analyst 10 [1885], p. 156 ; Ramsay and Williams, Chem. Soc. Journ. Trans. 49 [1886], p. 751.

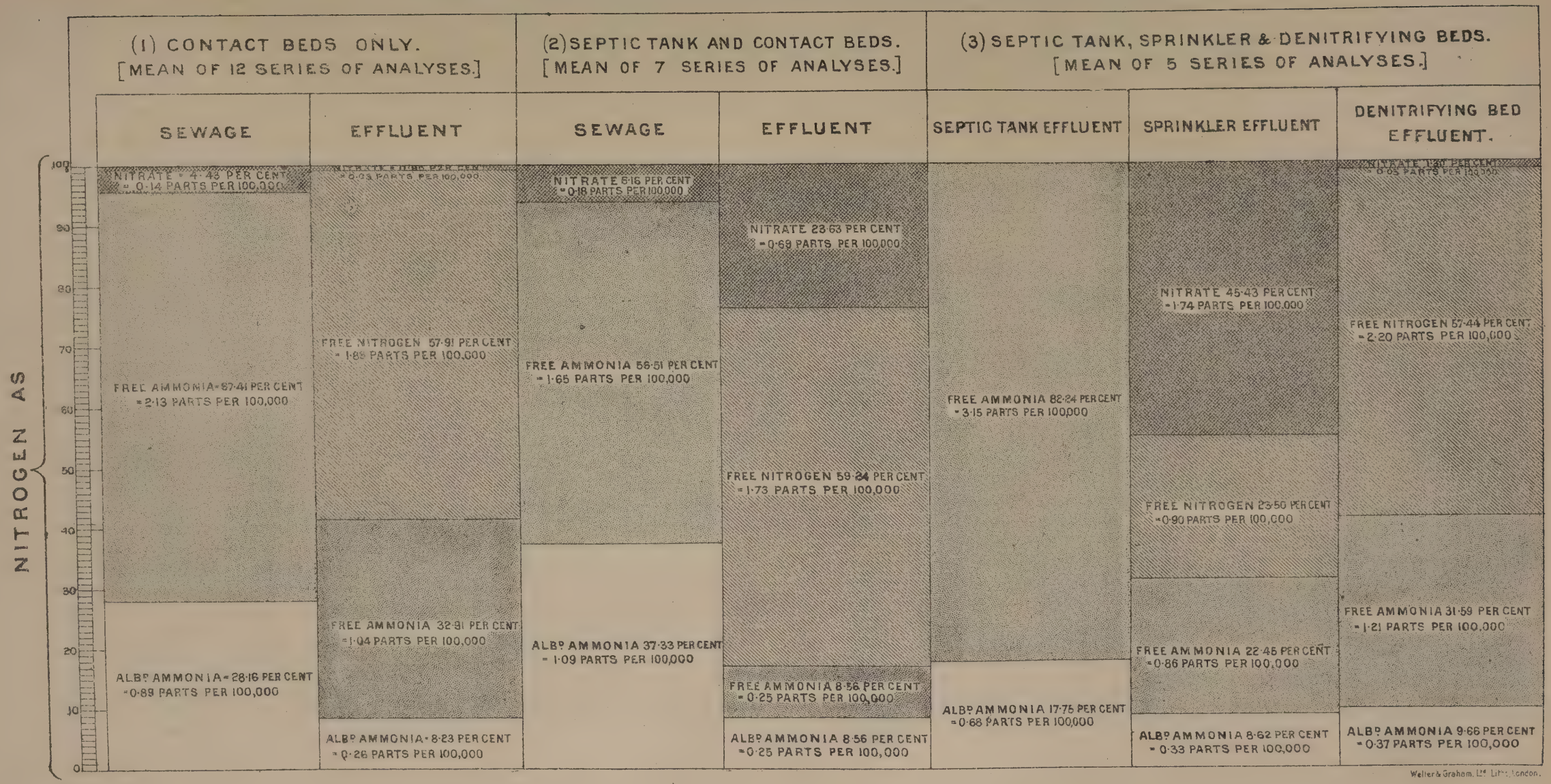
§ Chem. Soc. Journ. Trans. 55 [1889], p. 552.

‖ Chem. Soc. Journ. Trans. 57 [1890], p. 185.

Royal Commission on Sewage Disposal.

HANDED IN BY DR LETTS.

EFFECTS OF DIFFERENT METHODS OF TREATMENT ON SEWAGE.



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25deg.C., respectively, and the results compared with the gasometric determinations made by Roscoe and Lunt at the same temperatures. The greatest mean difference between the two sets of figures amounted to 0·09 c.c. of oxygen per litre of water, and the least to 0·02 Thresh makes the following remark:—"The results, however ,can be made to vary, the extreme limit being 0·5 mgs. (0·31 c.c.) of oxygen per litre of water, using 250 c.c. for the estimation."

One of the authors of this paper has employed this method on several occasions, but although every care was taken, and all the precautions mentioned in Thresh's memoir carefully observed, the results were not very satisfactory, and in the case of sea-water polluted with sewage they were definitely unsatisfactory. With distilled water, a variation of 0·4 c.c. of oxygen per litre from the true amount was found several times; while in the case of a polluted sea-water, some of the samples, when kept in stoppered bottles filled to the brim and immersed in water, actually showed a gain in dissolved oxygen when kept for twelve days, amounting in one of the samples to more than 0·6 c.c. per litre, although there cannot be the slightest doubt that a decrease had really occurred.

In the two volumetric processes mentioned above, the titration is performed in a vessel through which a current of hydrogen or other inert gas is made to pass, which not only complicates the operation, but renders a special apparatus necessary, and unfits the processes for "field" work.

Winkler's volumetric process* avoids the use of an inactive gas during titration. It is based upon the conversion of manganous hydrate into the peroxide by the dissolved oxygen of the water. Potassium iodide and hydrochloric acid are then added, and the liberated iodine (equivalent to the dissolved oxygen originally present), determined by titration with standard hyposulphite. Winkler draws attention to the disturbing effects of nitrites and easily oxidisable organic matter on the accuracy of the process, and in cases where these substances are present in the water under examination, provides against their disturbing effects by modifying the process in such a way that they are oxidised by manganic chloride, and a correction introduced. For this purpose a solution of manganese chloride is first added to the water, then caustic soda, and finally hydrochloric acid (twice the amount otherwise used), and after an interval of two or three minutes potassium iodide. During the interval it is assumed that the manganic chloride (produced by the solution of the peroxide in the hydrochloric acid) oxidizes the nitrite to nitrate, and also the easily oxidised organic matter, and as a consequence less iodine is liberated from the potassium iodide than corresponds with the dissolved oxygen, and less hyposulphite is required for the titration.

To arrive at the correction for this, distilled water is treated with caustic soda and manganous chloride, the precipitate dissolved in hydrochloric acid, and a solution of manganic chloride thus obtained.

Two experiments are then made, one with 100 c.c. of this solution mixed with 100 c.c. of distilled water, and a second with the same quantities of the solution and the water under examination. After two or three minutes potassium iodide is added to both, and the liberated iodine determined in each by standard hyposulphite. The difference in the volume of this latter required for the two solutions gives the value of the correction for 100 c.c. of the water, that is to say that figure to be added to the hyposulphite required for each 100 c.c. in the original determination.

Winkler's test experiments were made with distilled water, previously boiled, and then saturated with air (freed from ammonia and carbonic anhydride) in a water bath at constant temperature. The following results were obtained:—

T.	P.	Volume of dissolved oxygen per litre of distilled water calculated for 760 mm.
16·83	746·1	6·844 (mean of 6 experiments)
16·90	739	6·836 „ „ „
23·64	742·9	5·990 „ „ „

* Berichte d.d. Chem. Ges. 21·[1889], 2486.

These compare with the gasometric results obtained on the one hand by Dittmar*, and on the other by Roscoe and Lunt,† as follows:—

Winkler.		Dittmar.		Roscoe and Lunt.	
T °C		T °C		T °C	
16 83	6·844	16	7·06	16	6·82
		17	6.92	17	6.68
16·90	6·836	—		—	
23·64	5·990	23	6·18	23	5·94
		24	6·07	24	5·84

As regards the dissolved oxygen in impure waters, while Winkler gives certain results obtained with these by his volumetric method, he does not give any examples in which these results are contrasted with those obtained by gasometric analysis.

Rideal‡ has modified Winkler's method by submitting the water sample to a preliminary process of oxidation by acid permanganate, the excess of permanganate being then removed by potassium oxalate, and the rest of the process conducted as in Winkler's original method, with certain modifications as regards the strength of the solutions employed.

Ramsey and Homfrey's§ volumetric process depends upon the conversion of colourless ammoniacal cuprous chloride solution into blue ammoniacal cupric chloride by the dissolved oxygen in a given volume of the water, and a comparison of the depth of blue shade resulting, with that of a series of standard tubes representing from 1—8 c.c. of dissolved oxygen per litre.

The method is simple and rapid, and appears to give excellent results when approximate figures alone are required. The colour of the standard tubes gradually fades, hence these should be renewed at intervals.

The Authors' Process.

The principle of absorbing the dissolved oxygen in a water by ferrous sulphate and an alkali with subsequent determination of the unoxidised ferrous salt in the acidulated mixture by standard permanganate is an old one, and was first employed, we believe, by Mohr.‖

The method as carried out according to his directions is, however, open to several sources of error, of which, as we have proved, the use of permanganate as oxidising agent may, in certain cases, be one of the most serious. It also has the disadvantage of requiring the use of an inactive gas during part of the process.

While making use of the principle of this method to the extent that the dissolved oxygen in a water is absorbed by a ferrous salt plus an alkali (*i.e.*, by ferrous hydrate), and the excess of ferrous salt determined subsequently in the acidulated mixture by titration with an oxidising agent, we have sought to eliminate the various sources of error incidental to Mohr's process, and to avoid the use of an inactive gas during any part of the operations.

The whole process is simple, and one which a person of ordinary intelligence, but without any special chemical training, can be easily taught to perform. Stated briefly, it consists in adding a definite quantity of ferrous sulphate solution to a measured volume of the water under examination, and then excess of ammonia in a vessel which becomes entirely filled with the mixture and is then closed previous to mixing the three during the period necessary for the absorption of the dissolved oxygen. Sulphuric acid is then added in excess in such a way that no air can gain admission during the operation, after which the mixture is transferred to an open vessel, and there titrated either with standard permanganate or bichromate, according to the class of water under examination.

In order to eliminate the possible error due to easily oxidisable substances which may be present in the water, a blank experiment is made in an open vessel, in which the same volumes of the water, the ferrous sulphate solution and sulphuric acid are placed, and the titration performed with the same standard solution of

* Challenger Reports.
† Chem. Soc. Journ. [1889] (Trans.), p. 569.
‡ Analyst, Vol. 26 [1901], p. 141.
§ Journ. Soc. Chem. Industry, Nov. 1901.
‖ Lehrbuch d. Titrirmethoden 4 Aufl., p. 239.

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oxidising agent. The details of the method are as follow :—

STANDARD SOLUTIONS :—(1) *Ferrous Sulphates.*—12½ grams of the pure crystallised salt are weighed out on a rough balance, transferred to a 250 c.c. flask, dissolved in distilled water, 2-3 c.c. of pure sulphuric acid added, and the mixture diluted with distilled water until it occupies 250 c.c. Theoretically 12·444 grammes of the ferrous salt are required for a solution, each cubic centimetre of which is equivalent to 1 cubic centimetre of oxygen at N.T.P., but nothing is gained by preparing a solution of exactly this strength.*

(2) *Standard Permanganate.*—The most convenient solution is of such strength that 1 cubic centimetre is equivalent to 1 cubic centimetre of oxygen at N.T.P. ; and such a solution is obtained by dissolving 5·638 grammes of the pure crystallised potassium salt in 1 litre of distilled water.†

For the estimation of the dissolved oxygen in distilled water itself, or in ordinary (fresh) water, a solution of 1-10th this strength may be used ; but for all practical purposes the stronger solution will be found to give sufficiently accurate results, especially if a narrow burette of 10 c.c. capacity is employed. The stronger solution keeps well (in the dark), but the weaker one should be prepared freshly from the former for each series of experiments.

(3) *Standard Bichromate*, of a strength corresponding with that of the permanganate, may be employed instead of the latter ; and in the case of sewage effluents and in that of sea water is undoubtedly to be preferred, as will be shown by the results to be mentioned presently. Of course, in using bichromate, potassium ferricyanide must be employed as indicator ; and as the ferrous sulphate solution is highly diluted by the water under examination, the strong bichromate can alone be employed with advantage. This is prepared by dissolving 8·7906 grammes of the pure crystallised potassium salt in 1 litre of distilled water, each cubic centimetre of such a solution corresponding with 1 cubic centimetre of oxygen at N.T.P.

(4) *Sulphuric Acid.*—A mixture of equal volumes of the strong acid and water is employed. But we have also used a mixture of 3 volumes of the strong acid and 1 volume of water.

Absorbing Vessel.‡—The vessel in which the water under examination is mixed with the ferrous sulphate and ammonia, and in which, too, the mixture is afterwards acidulated with sulphuric acid, was in our experiment an ordinary separating vessel of the shape and capacity shown in the diagram (Fig. 1). The exact dimensions, however, are of no consequence, provided that the vessel holds about ⅓ litre of water and that the tube forming its lower extremity is wide enough to contain the quantity of sulphuric acid required to acidulate the ammoniacal mixture before titration.

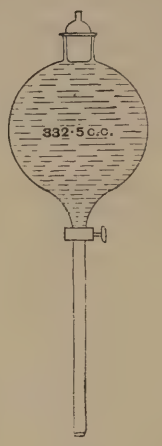


Fig. 1.

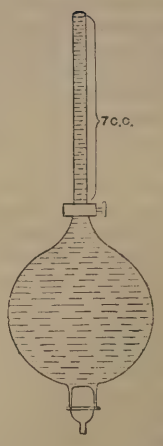


Fig. 2.

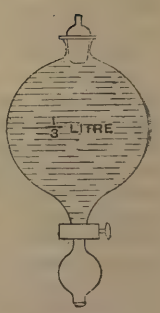


Fig. 3.

The Process.—The separating vessel is filled to the brim with the water under examination, and for this purpose we have always employed a glass siphon tube, one limb of which is dipped almost to the bottom of a Winchester quart bottle (filled originally to the brim and then stoppered) containing the sample of water, while the other and longer limb is connected with a piece of india-rubber tube clamped with a pinch-cock.

A little of the water is first drawn off and the separating vessel rinsed with it. The end of the rubber tube is then passed to the bottom of the separating vessel, the pinch-cock opened, and the water allowed to flow in until the vessel is not only full, but a fair quantity has overflowed. In this way the possibility of error owing to absorption of atmospheric oxygen by the upper layer of the water as it flows into the wide part of the vessel is avoided.

The stopper is now inserted, and the excess of water drained off. The stopper is next removed, and about 7 c.c. of the water taken out by a pipette and thrown away. 5 c.c. of the ferrous sulphate solution are then carefully measured off in an accurately graduated pipette and allowed to flow into the separating vessel, the nozzle of the pipette being just dipped below the surface of the water, when the ferrous sulphate, owing to its higher density, flows in a stream to the bottom of the water. Strong ammonia solution is then cautiously poured on to the top layer of the water until the vessel is just full, when the stopper is inserted ; but even if a drop or two of the ammonia is lost when inserting the stopper no harm is done, as the ammonia floats on the surface and does not appreciably mix with the contents of the vessel. A little dexterity is necessary in inserting the stopper so that no air bubble is enclosed. Within the separating vessel there is now a layer of ferrous sulphate below, next the water, and above all the ammonia. These are mixed together by inverting the vessel once or twice by a swinging motion, when a greenish turbid mixture results, containing ferrous hydrate partly in solution and partly in suspension, which rapidly darkens as it absorbs the dissolved oxygen. In all our first experiments an interval of 15 minutes was allowed for the purpose. Experience has shown it to be sufficient, but it is possible that a shorter period would suffice.* The next operation consists in inverting the vessel, still stoppered, and then filling or nearly filling its tube or lower extremity (now, however, its upper extremity) with the mixture of sulphuric acid and water (Fig. 2). The stop-cock is then opened, when the acid flows downwards into the alkaline mixture, and in the course of a few minutes dissolves the iron hydrates to a clear solution.†

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* The solution keeps fairly well, but unless a series of determinations is made with it at short intervals, it is advisable to re-standardise it on each occasion when it is used. The following figures will give an idea of the rate at which it becomes oxidized when kept in a stoppered bottle :

When made	5 c.c.	required	5·06	standard	bichromate.
After 5 days	,,	,,	5·01	,,	,,
,, 11 ,,	,,	,,	4·92	,,	,,

† A decinormal solution of the permanganate (3·164 grammes per litre) is also of a suitable strength for the titrations, 1 c.c. of this solution corresponding with 0·56 c.c. of oxygen at N.T.P.

‡ As an ordinary separating funnel is somewhat unwieldy for the purpose of these determinations, owing to the length of the tube, Messrs. Baird and Tatlock, of London, have constructed for us a special form of apparatus shown in the diagram (Fig. 3), which is very handy and convenient, and contains exactly ⅓ litre. The same firm also supplies the whole of the necessary apparatus and reagents for the determinations, packed in a box of portable form.

* More recent experiments have shown that a period of five minutes is sufficient, as the following results show :—

Dissolved oxygen in Belfast water supply (T. = 7·3) oxygen found after the ferrous hydrate had acted for :—

5 minutes.	10 minutes.	15 minutes.
8·34	8·37	8·37 c.c. per litre.

† In some of the test experiments with distilled water saturated with air this did not occur until the mixture was heated. But with all samples of natural waters, sewage effluents, &c., no heating was necessary.

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Should an air bubble remain in the boring of the stop-cock, it prevents this flow, but a few taps cause it to be displaced and to rise through the acid.

The presence of this air bubble can be avoided by opening the stop-cock for a moment when the absorbing vessel is being filled with the water sample. The acidulated solution is finally run off into a porcelain dish, and titrated either with the permanganate or bichromate solution.*

It remains to determine the value of the ferrous sulphate solution; and in our experiments this was always done under similar conditions to those obtaining in the dissolved oxygen determination itself, that is to say, the measuring vessel was filled with the water under examination, 7 c.c. removed, and the remainder poured into a porcelain dish, where it was mixed with the same volume of sulphuric acid† and the same volume of ferrous sulphate solution as were employed in the dissolved oxygen determination, and then titrated. In this way the error arising from oxidisable substances in the water is eliminated even when their amount is considerable.

In practice it was found convenient to standardise the iron solution during the interval required for the absorption of the dissolved oxygen, and consequently, as a preliminary to the latter process, to first of all fill the separating vessel with the water under examination and to transfer the latter (after removing 7 c.c.) to a porcelain dish ready for the addition of the sulphuric acid and ferrous sulphate.

Calculating the Results.—With the stronger solution of either the permanganate or bichromate, it is obvious that the amount of dissolved oxygen contained in the volume of water operated on is expressed in cubic centimetres at N.T.P. by the difference between the burette readings for the blank experiment and those of the actual determination—with a correction for the dissolved oxygen contained in the 5 c.c. of the ferrous sulphate solution and the 2 c.c. of ammonia. Such a correction is, however, small, and in all the authors' experiments the assumption was made that the 7 c.c. of mixed reagents contained the same proportion of dissolved oxygen as the water under examination.

The following table shows the results first obtained by the process, from which it will be seen that in the case of sewage effluents and sea water the use of bichromate as titrating agent gives much more accurate results than those obtained by permanganate:—

* A somewhat lengthy experience of the process when bichromate is used has satisfied us that when very accurate results are desired, attention should be paid to the following details:—(1) A clear crystal of potassium ferricyanide, or fragment of such crystal, about the size of a shot (say ⅛-inch in diameter), is placed on a small beaker, and washed two or three times with distilled water. It is then dissolved in about 10 c.c. of the same liquid. Some of this (straw-coloured) solution is drawn into a pipette with a fine capillary end, and a series of minute drops are placed by its means on a slab of milk glass. (A white tile is not so satisfactory, as it is liable to become stained after some time.) (2) In titrating, as large a drop as can be carried on a glass rod from the dish is jerked into one of the minute drops of the ferricyanide without touching the latter with the rod itself. The "end creation" is shown by there being no visible difference in colour after an interval of two minutes between the drops thus made and a similar one formed of distilled water and the ferricyanide. The end reaction is very sharp, and with a little experience is determined by less than 0·03 of the bichromate solution (about 1 drop from a 10 c.c. burette). (3) Strong sunlight disturbs the end reaction in the case of polluted waters (probably by the well-known reducing effect of light on a ferric salt in presence of organic matter). This can be easily demonstrated by placing on the white glass slab two similar drops of the ferricyanide and the titrated mixture when the end reaction has just occurred—shading one (say with a pill-box lid) and exposing the slab to sunlight for a few minutes, when the unshaded drop becomes blue, while the shaded drop remains faintly yellow. This action is especially noticeable with polluted sea water. The titration can be performed by artificial light—preferably incandescent electric light, the end reaction being very sharp. (4) As only 5 c.c. of the standard bichromate are required at maximum for each titration or standardization, a burette of this capacity and divided into twentieths of a cubic centimetre might be advantageous for very accurate work.

† This should always be added before the ferrous sulphate, otherwise ferrous carbonate may be precipitated and absorb dissolved oxygen.

Thus, in one of the determinations, the difference between the burette readings for the blank and dissolved oxygen determinations was 2·35 c.c. Assuming that the 7 c.c. of reagent added contained the *same* amount of dissolved oxygen as the water under examination, then the latter contained per litre—

$$\frac{2350}{332\cdot5} = 7\cdot067 \text{ c.c. dissolved oxygen, per litre, at N.T.P.}$$

Whereas assuming that the 7 c.c. of reagents contained *no* oxygen, the figures become—

$$\frac{2350}{325\cdot5} = 7\cdot219 \text{ c.c. dissolved oxygen, per litre, at N.T.P.}$$

The difference is 0·152 c.c. per litre, which, for most practical purposes, is unimportant, and the actual error would certainly be much less. The error, so far as the ferrous sulphate solution is concerned, could be eliminated by saturating it with air at the given temperature previous to a determination, while that from the small volume of ammonia added is too insignificant to need correction.

DISSOLVED OXYGEN DETERMINATIONS (1).

COMPARISON OF RESULTS obtained by the Authors' Volumetric Method with those obtained by Gasometric Analysis or with the Air Saturation Figures. (Results in c.c. per litre, N.T.P.)

Nature of Sample Analysed.	Volumetric Result (Permanganate).	Volumetric Result (Bichromate).			Difference referred to Volumetric Result.
Distilled water aërated at 15° C.	7·06	—	7·20	Dittmar's air saturation figure 15° C.	−0·14
			6·96	Roscoe and Lunt's " " "	+0·10
" " " 13·7	7·26	—	7·42	Dittmar's " " 13·5	−0·16
			7·20	Roscoe and Lunt's " " "	+0·06
" " + 1 per cent. foul sewage, aërated at 15.	7·13	—	7·20	Dittmar's " " 15·0	−0·07
			6·96	Roscoe and Lunt's " " "	+0·17
Belfast water supply	5·80	—	5·75	Gasometric result	+0·05
Sewage effluent from storage pond	2·71	—	3·15	" "	−0·44
Sea water from Belfast Lough	5·09	—	4·50	" "	+0·59
" " " aërated at 19·5	5·35	5·41	5·36	Dittmar's air saturation figure 19·5	−0·01
					+0·05
" " " " 20·8	5·53	5·11	5·10	Gasometric result	+0·43
					+0·01
Sewage effluent	0·66	0·42	0·35	" "	+0·31
					+0·07
Untreated sewage	0·13	0·00	0·00	" "	+0·13
					0·00

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Effects of Nitrates and Nitrites.—In order to ascertain whether the presence of nitrates or nitrites would interfere with the accuracy of the process, parallel determinations were made of the dissolved oxygen in aerated tap water alone, and in the same water to which a definite proportion of nitrate or nitrite had been added. The following table shows the results obtained :—

EFFECT OF NITRATES.

Dissolved Oxygen found in Aërated Tap Water alone (c.c. per Litre at N.T.P.).	Dissolved Oxygen found in the same Water to which Potassium Nitrate was added (c.c. per Litre at N.T.P.).	Nitric Nitrogen (parts per 100,000) equivalent to the added Nitrate
7·37	7·34	1·0
7·55	7·49	14·3

EFFECT OF NITRITES.

Dissolved Oxygen found in Aërated Tap Water alone (c.c. per Litre at N.T.P.).	Dissolved Oxygen found in the same Water to which Sodium Nitrite was added (c.c. per Litre at N.T.P.).	Nitrous Nitrogen (parts per 100,000) equivalent to the added Nitrite.
7·46	9·96	1·43
7·47	7·82	0·143
7·71	7·68	0·012

From these results it seems evident that the presence of nitrates in a water, even in considerable quantities, scarcely, if at all, affects the dissolved oxygen determination by the new process.

On the other hand, the presence of nitrites evidently exercises a very distinct disturbing effect, of such a nature that too much oxygen is found. It is a well-known property of nitrites that they sometimes behave as oxidising and at others as reducing agents and the explanation of their interference with the accuracy of the process is probably to be found in their exercising an oxidising action on the precipitated ferrous hydrate, thus behaving like the dissolved oxygen itself.

From the results recorded above it appears that the process ceases to give accurate results when the quantity of nitrite corresponds with 0·143 parts per 100,000 (0·1 grain per gallon) of nitrous nitrogen, but when the quantity is only one-tenth as much no perceptible error is introduced.

In all probability the process would give sufficiently accurate results for all practical purposes in waters containing nitrous nitrogen up to 0·05 grain per gallon. We desire to express our thanks to Dr. John Hawthorne, M.A., for the valuable assistance he rendered us in carrying out the above experiments on the effects of nitrates and nitrites.

Further Proofs of the Accuracy of the Method.—Although the evidence which we have given above might be considered as amply sufficient to establish the accuracy of the new process, and its suitability for the determination of dissolved oxygen in all classes of natural waters as well as in sewage effluents, we were induced to make a more extended series of comparative tests in order to establish as far as possible beyond all question the value of the method.

The figures given in the following table include *every* result, in chronological order, obtained during this investigation :—

DISSOLVED OXYGEN DETERMINATIONS (2).

COMPARISON OF RESULTS obtained by the Volumetric (Bichromate) Method with those obtained by Gasometric Analysis or with the Air Saturation Figure.

Date.	Nature of Sample Analysed.	Volumetric Result.	———	———	Difference referred to Volumetric Result.
—	Distilled water saturated with air at 12·3° C.	7·71	7·66	Dittmar's figure for 12° C.	+ 0·05
—	,, ,, ,, ,, ,,	7·65	7·66	,, ,, ,,	− 0·01
—	Sea ,, ,, ,, 13·1	6·18	6·06	,, ,, 13° C.	+ 0·12
—	,, ,, ,, ,, ,,	6·18	6·06	,, ,, ,,	+ 0·12
Oct. 25, 1904	,, ,, mouth of Lagan R., high tide	3·81	3·64	Gasometric analysis	+ 0·17
,, ,, ,,	,, ,, outside Lighthouse, Belfast Lough.	5·85	5·83	,, ,,	+ 0·02
,, ,, ,,	,, ,, Greypoint, Belfast Lough	5·94	5·96	,, ,,	− 0·02
Nov. 28, ,,	,, ,, plus 1 % sewage, aërated	6·48	6·47	,, ,,	+ 0·01
Dec. 2, ,,	Same liquid kept in stoppered bottle	5·58	5·42	,, ,,	+ 0·16
,, 20, ,,	,, ,, ,, ,, ,,	4·42	4·22	,, ,,	+ 0·20
Jan. 16, 1905	,, ,, ,, ,, ,,	3·69	3·57	,, ,,	+ 0·12
Dec. 5, 1904	Water from Lagan River at Albert Bridge	6·99	7·04	,, ,,	− 0·04
,, ,, ,,	,, ,, ,, ,, ,, its mouth	6·03	6·03	,, ,,	+ 0·00
,, 6, ,,	Sea water near Lighthouse, Belfast Lough	6·42	6·44	,, ,,	− 0·02
,, ,, ,,	,, ,, ,, Cultra ,, ,,	6·39	6·37	,, ,,	+ 0·04
,, ,, ,,	,, ,, ,, Holywood ,, ,,	6·39	6·39	,, ,,	± 0·00
Jan. 11, 1905	Water from a manhole in a Belfast Street	6·60	6·74	,, ,,	− 0·14

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Cases in which the Method, unless modified, ceases to give Accurate Results.—After the completion of the series of test experiments just recorded, a liquid came under investigation in which a serious discrepancy was found for the first time between the figures obtained for the dissolved oxygen by the gasometric and volumetric methods of analysis. The liquid in question resulted from the treatment of sewage by a septic tank and eventually by a "sprinkler" or continuous filter, and had been kept in a stoppered bottle for some days. It formed part of the series employed in the experiments on the changes which such an effluent experiences when kept. In this liquid *no* dissolved oxygen was found by gasometric analysis, while a determination by the volumetric method (bichromate) showed no less than 1·56 c.c. per litre. The liquid examined by the same method of analysis at further intervals of time showed in succession 1·20, 0·78, and 1·14 c.c. per litre.

How can these anomalies be explained? It seems clear that the liquid under examination must have contained easily reducible compounds which oxidised some of the ferrous hydrate, and as nitrites were practically absent, and we have, as already mentioned, proved that nitrates do not appreciably affect ferrous hydrate, the question arises whether during the gradual process of denitrification which it has been shown that the effluent experiences, unstable oxidised nitrogenous compounds, possibly of the nature of nitro or nitroso bodies, may not have been formed.

It is also possible that the easily reducible compound contained no nitrogen, but was an unstable intermediate product arising from the oxidation of the carbonaceous constituents of the effluent before their final resolution into carbonic anhydride; but this view seems less probable than the first, as the analysis of the dissolved gases indicates that the formation of carbonic anhydride occurs *pari passu* with the disappearance of the dissolved oxygen and the nitrate. Whatever the chemical nature of the easily reducible compound may be, it can scarcely be doubted that such a substance is formed, and that it materially affects the accuracy of the volumetric process. Two methods suggested themselves for removing it, or, rather, for preventing its disturbing effects—one to oxidise it to a more stable compound which would not be reduced by ferrous hydrate, and the other to reduce it with a similar object. Both methods were tried, and both led to a partial correction of the error in the volumetric process. As reducing agent sulphurous acid was used, and as oxidising agent acid permanganate. After a number of trials with both of these reagents it was found that a preliminary treatment of the effluent with acid permanganate led to the more satisfactory correction, and that the following modification of the volumetric process gives results which are at least sufficiently accurate for practical purposes:—

A solution of acid permanganate (freshly prepared before each series of determinations, as it does not keep well) is made by mixing three volumes of the permanganate solution used for the dissolved oxygen determinations (1 c.c. = 1 c.c. of oxygen at N.T.P.), with one volume of the diluted sulphuric acid (equal volumes of water and the concentrated acid). Two c.c. of this mixture are then added from a pipette to the effluent contained in the measuring vessel used in the volumetric method. The stopper of this vessel is then inserted, and its contents mixed with a swinging motion, after which they are allowed to remain for ten minutes; 7 c.c. are then removed, the ferrous sulphate and ammonia added, and the process carried out in the usual manner.

The blank experiment is conducted in precisely the same way, with the difference that after removing 7 c.c. of the permanganated liquid and adding the ferrous sulphate, sulphuric acid is added instead of ammonia, and the mixture at once run off into a dish and titrated.

In the following table we give the results of the different determinations of dissolved oxygen we have made in the "sprinkler" effluent by both the modified and unmodified volumetric method, as well as by gasometric analysis.

It will be seen that the effluent when recently collected gives fairly accurate results with the unmodified volumetric process, and that serious error only occurs after it has been kept for some time. It should be mentioned that in the experiments with sulphurous acid 1 c.c. of a solution (approximately of the strength 1 c.c. = 1 c.c. of the permanganate = 1 c.c. of oxygen) was added to the effluent in the measuring vessel, and allowed to act for the same time and in the same manner as already described for the acid permanganate.

In the first experiment (B.3) with acid permanganate only 1 c.c. of that reagent was employed, and it was allowed to act on the effluent for five minutes only, but, as the correction thus obtained was evidently too low, in all the other experiments (A.4. C.1. C.2. C.3 and B 4, in chronological order) twice that quantity of acid permanganate was added, and the time interval during which it was allowed to act on the effluent was also doubled.

It will be seen that bichromate was used as titrating agent in most of the determinations, but we believe that permanganate would have given equally good results, and would probably be preferred by most people.

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DISSOLVED OXYGEN IN THE EFFLUENT FROM A "SPRINKLER" KEPT UNDER ANÆROBIC CONDITIONS.

Nature of Sample Analysed.	Determinations by the Volumetric Method without preliminary Treatment.		Determinations by Gasometric Analysis.	Determinations by the Volumetric Method after preliminary Treatment with:		
				Sulphurous Acid.	Acid Permanganate.	
	Titrations by $K_2Cr_2O_7$.	Titrations by $KMnO_4$.		Titrations by $K_2Cr_2O_7$.	Titrations by $K_2Cr_2O_7$.	Titrations by $KMnO_4$.
SERIES A.						
(1) 5 days after collection -	1·56	—	0·00	—	—	—
(2) 9 „ „ „ -	1·20	—	0·10	—	—	—
(3) 14 „ „ „ -	0·78	—	0·00	—	—	—
(4) 20 „ „ „ -	1·14	—	0·00	0·36	0·24	—
SERIES B.						
(1) When collected - -	7·02	—	6·84	—	—	—
(2) 24 hours after collection -	5·44	—	5·13	—	—	—
(3) 5 days „ „ -	1·68	—	0·08	—	0·90	—
(4) 7 „ „ „ -	—	—	0·00	—	0·00	—
SERIES C.						
(1) When collected - -	6·69	6·54	6·20	5·52	6·39	—
(2) 4 days after collection -	1·35	—	0·50	—	0·12	—
(3) 17 „ „ „ -	1·77	—	0·00	—	0·21	0·09

SEVENTY-NINTH DAY.

Thursday, 18th May, 1905.

PRESENT:

The Right Hon. the EARL of IDDESLEIGH (*Chairman*), presiding.
Major General CONSTANTINE PHIPPS CAREY, C.B., R.E.
Colonel T. W. HARDING, J.P.
Sir WILLIAM RAMSAY, K.C.B., F.R.S.
Mr. T. J. STAFFORD, F.R.C.S.I.

Mr. F. J. WILLIS (*Secretary*).

ALSO PRESENT:

Dr. A. C. HOUSTON,
Dr. GEORGE MCGOWAN.
Mr. G. B. KERSHAW.
Mr. C. C. FRYE.

MR. J. D. WATSON, M. INST. C.E., ENGINEER TO THE BIRMINGHAM, TAME, AND REA DISTRICT DRAINAGE BOARD, AND MR. F. R. O'SHAUGHNESSY, CHEMIST TO THE DRAINAGE BOARD, called in; and Examined.

24913. What is the general scheme of sewage disposal at Birmingham?—(*Mr. Watson.*) Sedimentation, septic tanks, percolating filters, and land treatment.

24914. What is the population draining to your works?—Appended hereto is a statement showing the population draining to the Sewage Disposal Outfall Works in 1901, the date of the last census, and the estimated population draining to the works, March 31st, 1905. I also append the figures which represent the yearly rate per cent. of increase in population during the decade immediately preceding the last census in 1901. The various authorities whose populations are given herewith are united together under the jurisdiction of a representative joint authority, constituted for purposes of main sewerage and sewage disposal, such authority is called the Birmingham, Tame, and Rea District Drainage Board.

Statement of Population.

Name of place or Authority.	Population, Census 1901.	Yearly rate per cent. of increase in population, 1891–1901.	Estimated population, March 31st, 1905, assuming same percentage of increase.
City of Birmingham	522,182	·92	541,475
Borough of Aston Manor	77,310	1·26	81,227
„ Smethwick	54,560	5·09	65,911
„ Sutton Coldfield	14,234	6·42	18,030
Urban District of Handsworth	52,921	6·33	66,657
„ „ Kings Norton	50,000	7·67	65,851
„ „ Erdington	16,366	6·99	23,500
„ „ Perry Barr (part of)	150	—	150
Rural District of Castle Bromwich	2,743	1·46	2,900
Total	790,496		Total 865,701

24915. What is the system of drainage—that is to say, is the storm water either wholly or partially drained into a separate system, and if only partially, to what extent ?—The system of drainage throughout the Board's district varies in character. Speaking generally, it may be said that the older and more populous portions of the district, which represent also the greater part of the paved areas and mainly consist of the greater portion of the city of Birmingham and the borough of Aston Manor are drained on the "combined" system. During the last five years this system, in the districts referred to, has been supplemented by the construction of a series of storm intercepting drains in order to relieve the foul water sewers of surplus flow in time of excessive rainfall. The remaining portions of the districts embodied in the drainage area, being mainly suburban, have been and are now being drained on a partially separate system; that is to say, that a system of surface water sewers intercept the rain water flowing from the carriage and footways, front gardens and front roofs of houses. The remainder of the rainfall, which comes from the back roofs and yards attached to the houses, being connected into the foul water sewers. The following table indicates the relative areas drained in accordance with the systems previously referred to:—

Name of Authority.	Area sewered on the "combined" system. Acres.	Area sewered on the separate or partially separate system. Acres.
City of Birmingham	8,639	4,000
Borough of Aston Manor	943	—
„ Smethwick	797	796
„ Sutton Coldfield	—	5,000
Urban District of Handsworth	1,220	687
„ „ Kings Norton	6,140	4,000
„ „ Erdington	—	4,550
„ „ Perry Barr (part of)	—	30
Rural District of Castle Bromwich	—	200
Total	17,739	19,263

It is not practicable for me to say what percentage of the rainfall enters the foul water sewers throughout the whole district, but as the result of observations in respect of the two suburban districts of Harborne and Edgbaston, situated within the city of Birmingham, both of which are extensive, and are sewered on the partially combined system, it is estimated that about three-eighths of the total rainfall would pass into the surface or storm water sewers, and the remaining five-eighths would pass through the foul water system of sewers.

24916. Is there any infiltration of subsoil water into the sewers ?—There is undoubtedly infiltration of subsoil water into the sewers of this district, but the data is not available upon which even approximately the relation of the volume in proportion to the total dry weather flow of sewage could be stated. There is evidence that the older sewers are generally responsible for the greater portion of whatever subsoil leakage there may be. Newly laid sewers admit very little subsoil water, the amount of subsoil water which filters into the sewers generally

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throughout the whole of the Board's district is not in any sense extensive or serious.

24917. What is the water supply per head, and from what source does it come?—There are two main sources of water supply in the district. First, City of Birmingham water supply, which is distributed over 44,283 acres of the drainage district. About one half of this supply is still derived from local sources (*i.e.*, from wells, bore holes, and some upland gathering ground.) The remaining half of the water comes from the gathering ground at Rhayader in Radnorshire. It is expected that the latter will be the only source of supply within the course of a few months. The average daily consumption per head for all purposes in this area of supply is 24·03 gallons. Secondly, the South Staffordshire Waterworks Company distributes its supply over an area of 16,146 acres, which includes the Boroughs of Sutton Coldfield and Smethwick. The source of this supply is a local one, being mainly derived from wells or bore holes sunk in the new red sandstone formation. The average daily consumption per head for all purposes in this area of supply is 20 gallons.

24918. Is it hard or soft water?—The City of Birmingham Welsh supply is a soft one, having in all only 2·3 degrees of hardness. The old water supply derived from local sources and supplied by the City of Birmingham is hard, having a total of 28 degrees of hardness. A complete analysis of the old local supply, and of the new or Welsh supply, is as follows:—

(Expressed in parts per 100,000.)

———	Total solids.	Free Ammonia.	Ammonia, albuminoid.	Nitric nitrogen.	Oxygen absorbed in 4 hours.	Chlorine in chlorides.	Alkalinity.
Old supply - -	39·8	·001	·006	·22	·18	1·9	16·8
New supply - -	6·0	—	·004	—	·20	1·0	2·3

The South Staffordshire water supply coming from various sources, is subject to some variation, but the average composition may be taken to be as follows:—

(Expressed in parts per 100,000.)

Free Ammonia.	Ammonia albuminoid.	Nitric nitrogen.	Oxygen absorbed in 4 hours.	Total solids.	Lime.	Magnesia.	Sulphuric anhydride.	Sodium oxide.	Chlorine.	Nitric anhydride.	Oxide of iron and alumina.	Silica.	Total degrees of hardness.
·0015	·003		·080	37·14	9·4	1·3	3·73	2·35	2·07	1·4	·17	·7	10·5

The total hardness of this water is 10·5 degrees.

24919. What is the drainage area of the part of the town which is sewered?—I am unable to say with exactitude what the nett drainage area is, which is provided with a sewerage system, and connected to the Board's Outfall Works. Approximately, I estimate the nett area of the sewered areas within the Board's Drainage District, and connected to the Board's Outfall Works, to be as follows, and for comparative purposes I attach also the gross areas of the Sanitary Authorities:—

———	Gross area of Authority.	Net area sewered to Board's outfall.
	Acres.	Acres.
City of Birmingham - - - -	12,639	12,639
Borough of Aston Manor - -	943	943
,, Smethwick - - -	1,929	1,593
,, Sutton Coldfield - -	12,828	5,000
Urban District of Handsworth -	3,665	1,907
,, ,, Kings Norton -	11,900	10,140
,, ,, Erdington - -	4,550	4,550
,, ,, Perry Barr - -	4,042	30
Rural District of Castle Bromwich	7,724	200
Total - - - -	60,220	37,002

24920. What proportion of the population use pail closets or middens, and what proportion use water-closets?—The proportion of the population using pail closets or middens, together with the proportion using water-closets is given in the appended statement.

Statement.

Name of Authority.	Proportion of population using pail closets or middens.	Proportion of population using water closets.
	Per cent.	Per cent.
City of Birmingham -	30	70
Aston Manor - - - -	33	67
Kings Norton - - -	4	96
Handsworth - - - -	8	92
Erdington - - - - -	7	93
Sutton Coldfield - - -	6	94
Smethwick - - - -	25	75

24921. Has the flow of sewage to your Works been gauged? If so what is the average number of gallons delivered at the Works per day of twenty-four hours in dry weather, in winter and in summer?—Continuous gaugings of the total flow of sewage to the Outfall Works have been taken from January 1st 1905 to the present time—a period of four months The average dry weather flow

recorded is at the rate of 21,970,000 gallons per twenty-four hours. The following table shows the comparative hourly volume and variation in flow of the average daily dry weather flow of sewage and is based upon continuous gaugings extending over four months, January 1st to April 31st, 1905:—

Time of flow.	Dry weather flow. Volume discharged.	Hourly percentage of total daily flow.	Time of flow.	Dry weather flow. Volume discharged.	Hourly percentage of total daily flow.
12 to 1 a.m.	654,000	2·98	1 to 2 p.m.	1,363,000	6·20
1 to 2 „	614,000	2·79	2 to 3 „	1,346,000	6·13
2 to 3 „	577,000	2·63	3 to 4 „	1,312,000	5·97
3 to 4 „	540,000	2·46	4 to 5 „	1,264,000	5·75
4 to 5 „	505,000	2·30	5 to 6 „	1,208,000	5·50
5 to 6 „	478,000	2·17	6 to 7 „	1,144,000	5·21
6 to 7 „	510,000	2·32	7 to 8 „	1,066,000	4·85
7 to 8 „	607,000	2·76	8 to 9 „	985,000	4·48
8 to 9 „	708,000	3·22	9 to 10 „	900,000	4·10
9 to 10 „	900,000	4·10	10 to 11 „	808,000	3·68
10 to 11 „	1,142,000	5·20	11 to 12 „	716,000	3·26
11 to 12 „	1,283,000	5·84	Total dry weather flow - - - -	21,970,000	100·00
12 to 1 p.m.	1,340,000	6·10			

24922. What is the maximum dry weather rate of flow, and at what hour does this occur ?—The average maximum flow during the day in dry weather is at the rate of 35,560,000 gallons per twenty-four hours. This occurs generally about 1.30 p.m.

24923. What is the minimum dry weather rate of flow, and at what hour does this occur ?—The minimum flow during the dry in day weather is at the rate of 10,560,000 gallons per twenty-four hours. This occurs generally about 6.0 a.m.

24924. What is the maximum wet weather rate of flow which you have observed coming to the works, and during how many hours has this continued ?—The maximum rate of flow which has been measured as flowing to the Outfall Works during storm times has been approximately at the rate of 260,000,000 gallons per 24 hours. This rate of flow has lasted for about 1 hour.

24925. What storm overflows have you on your sewers, and at what rate or rates of flow do they come into operation ? For comparative purposes kindly give the maximum and minimum rates of flow in dry weather in the sewers on which the various overflows are situated ?—There are 80 storm water overflows on the sewers within the area of the City of Birmingham; about 40 of this number are defective, that is, discharge when the sewer is under a head only, and the remaining 40 are free. Twenty-five of these overflows discharge at 6 dilutions, and the remaining 55 at rates varying from 6 to 10 dilutions. The variation between maximum and minimum rate of dry weather flow in the sewers on which overflows are placed is estimated not to exceed a variation of 4 to 1.

24926. What is the largest number of gallons of sewage which have passed the last storm overflow, and come to your works in 24 hours ?—Continuous gaugings have been taken during the four months ending April, 1905—(the rainfall being only 50 per cent. of the average) —and the largest number of gallons registered during any 24 hours period was 82,000,000 gallons.

24927. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area ?—The average yearly rainfall as obtained from results of meteorological observations at the Edgbaston Observatory is given as 24·871 inches. This quantity computed over a drainage area of approximately 90 square miles gives a quantity of 32,500,000,000 gallons.

24928. Can you give the Commission an approximate statement as to the volume of sewage which comes to your works during the year, and the volume which passes over your overflows ?—It is estimated that the total volume of sewage and storm water flowing through the sewers to the Board's outfall works at the present time amounts to 9,560,000,000 gallons per annum, based upon an average annual rainfall of 24·87 inches. No records of the volume which passes over the overflows are available.

24929. Does the infiltration of subsoil water into the sewers occur regularly, or does it vary with the seasons or with the state of the weather, and can you give an approximate idea of the extra amount of liquid at one and another time entering the sewers from this source ?—No data is possessed from which could be given even approximately the quantity of infiltration water entering the sewers at one time or another. The quantity is small, and although it probably varies with the seasons of the year, no information is possessed with regard to the extent or nature of the variation.

24930. How many gallons of trade effluents enter the sewers daily (24 hours), and what is the nature of these effluents?—The estimated average volumes of liquid trades waste discharged into the sewers, amounts to approximately 4,000,000 gallons per diem. They are very varied in character. The predominant characteristic being trades waste from metal working industries.

Acid Trade Effluents.—The chief sources of these are the pickling and finishing processes of metal workers. The acid reaches the sewer in various states of dilution, usually carrying in solution a certain amount of metal. The principle metallic constituent is iron, but appreciable quantities of copper, zinc, and other metals are also present. Owing to the greater care now taken by copper and brass workers in recovering the copper, much less is discharged into the sewers than formerly. The quantities of acid used by about 350 manufacturers per week has been computed to be as follows:—

Sulphuric acid - - -	1,000 carboys
Nitric acid - - - -	646 carboys
Hydrochloric acid - - -	1,100 carboys

(1 carboy = 10 gallons).

Non-acid Trade Effluents.—Slaughter houses, breweries, pen manufactories, etc., contribute non-acid refuse, and a very appreciable quantity of fatty and oily matter finds its way into the sewage.

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Alkaline Trade Effluents.—About a dozen firms, comprising chemical manufacturers, fellmongers, paper manufacturers, etc., discharge alkaline liquors into the sewers. The principal constituent of these discharges is lime, and the total quantity of lime used by these people is about 100 tons per week.

24931. Has your authority framed any rules as to the reception of trade effluents into sewers? If so, what are they?—This authority follows two rules with regard to the reception of trade effluent into sewers; 1st, relating to effluents, containing solids in suspension and 2nd, those effluents containing acids in solution and in respect of new connections into the sewers for noxious effluents.

(a) *Trade Effluents, containing Solids in Suspension.*—It is understood that 75 per cent of the total suspended solids in liquid trades wastes shall be eliminated before the liquid is admitted into sewers.

(b) *Acids in solution.*—Large volumes of acid liquor are not allowed to be discharged into sewers at one time. The daily volume to be discharged shall flow evenly and continuously from the works, the outlet pipe being of such a size as to ensure this condition being fulfilled.

This latter condition has been enforced within the last five years in respect of those manufacturers who were already connected with the sewers. In not more than one or two instances has it been found necessary to threaten legal proceedings to enforce these rules, so willing have manufacturers been to comply with a reasonable request.

So long as the combination of trades waste and domestic sewage can be treated (without extra cost), on biological lines the Board do not propose to interfere unduly with manufacturers discharging effluents which inhibit bacterial growths.

24932. Do you find that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume, or otherwise? If so, would you kindly tell us what your difficulties are?—Much serious trouble has been caused at different times by sudden discharges of large quantities of trade effluents, such as waste gas liquor containing much tarry matter, or waste pickling liquor. Normally however, the discharge of such liquors is fairly uniform and the most persistent difficulty encountered in certain portions of the sewage, is the trouble experienced in attempting to set up septic action. This is attributed to the low alkalinity accompanied by the presence of ferrous salts. After mixing with the other sewage this difficulty disappears. On one or two occasions field crops have been destroyed entirely by being treated with acid sewage from one of the sewers.

24933. In dry weather what is the average amount of suspended matter in your sewage, and what are the highest and lowest figures in parts per 100,000?—The average amount of suspended matter in Birmingham sewage (average) is 71·9 (an average of 500 samples taken over four years).

The highest observed figure is - 1,044·5
The lowest observed figure is - - 16·9

It may be pointed out that these figures are quite exceptional and are not included in the above average. There have been several figures between 300–400.

24934. What is the physical character of these solids?—The suspended solids vary greatly in character. They include much fine sand, gravel, particles of coal, cinders, wood, leather, animal hairs and bristles, animal fat, paper, fragments of food, vegetable matter, and much fæcal matter. Occasionally large pieces of wood, metal, rags, and bodies of small animals make their appearance in the sludge.

24935. Can you give us average analyses of your sewage for the years 1903 and 1904 in summer and in winter?—Yes, as follows:—

1903, *Winter.*

	Dissolved solids.	Suspended solids.	Free ammonia.	Albumin'd ammonia.	Chlorine.	Nitrates and nitrites as nitrogen.	Oxygen absorbed.	
							Unfiltered.	Filtered.
Saltley Sewage - -	146·0	47·5	3·071	0·840	10·7	0·632	17·981	9·509
Rea ,, - -	141·5	58·4	3·013	1·493	23·5	0·569	26·129	17·614
Hockley ,, - -	125·4	63·1	2·100	1·103	21·7	0·554	23·696	12·643
Aston ,, - -	103·2	155·5	3·505	1·648	15·3	0·920	25·913	12·101
			1903, *Summer.*					
Saltley Sewage - -	135·9	57·2	3·403	1·005	13·0	0·805	20·778	10·301
Rea ,, - -	117·4	55·5	2·992	1·112	21·3	0·850	26·796	15·268
Hockley ,, - -	125·0	66·9	2·920	1·149	21·7	1·180	26·881	14·388
Aston ,, - -	123·5	73·6	2·910	1·283	19·4	·831	24·024	12·101
			1904, *Winter.*					
Saltley Sewage - -	142·9	53·5	3·226	1·149	12·8	—	24·591	15·174
Rea ,, - -	113 9	65·0	3·056	1·415	21·3	—	31·749	23·582
Hockley ,, - -	108·4	53·2	2·800	1·026	18·4	—	23·928	14 146
Aston ,, - -	92·2	59·4	2·793	1·137	14·1	—	21·725	13·954
			1904, *Summer.*					
Saltley Sewage - -	141·3	35·6	3·955	·956	16·5	—	17·944	10 130
Rea ,, - -	114·2	63·4	4·515	1·391	21·0	—	24 652	12 641
Hockley ,, - -	121·5	58·5	4·787	1·379	21·1	—	23·799	11 709
Aston ,, - -	116·3	122·0	4·675	2·213	17·0	—	26·861	9 300

24936. Is it a "strong" sewage, and, if so, what characterises its strength?—Birmingham sewage is a "strong" sewage. Putrescible matter of all descriptions may be said to characterise the "strength" of this sewage, and the amount of "oxygen absorbed in four hours at 80 F." may be said to measure the strength most closely.

24937. Does its strength vary very much from hour to hour or on different days of the week, and, if so, do these variations affect the quality of your final effluent to a marked degree?—Certain portions of the sewage vary greatly in strength from hour to hour, the liquid during the early hours of the morning having the appearance of tap water, whereas in the afternoon it is extremely foul and turbid. The variation from day to day is most marked at the beginning of the week. The difference in quality between sewage taken at other times has not been observed to be considerable. The quality of the land effluent does not seem to be affected much thereby; but variation in the quality of the sewage supplied to bacteria beds produces corresponding marked effects in the effluents from such beds.

24938. How do you think "strength" of sewage as affecting purification is best expressed or measured?—"Strength" of sewage as affecting purification may be measured by comparing the figures for "Albuminoid Ammonia" and for "Oxygen absorbed in four hours at 80 F" in the sewage and the effluent respectively. The purification both actual and potential may be best measured by the figure called "oxygen conferred on the sewage." This figure is in fact an approximate measure of the work done in purifying the sewage. It is obtained as follows:—

Let. O = "Oxygen conferred on sewage." in pounds per day.
„ S = Oxygen absorbed by sewage in four hours at 80 F.
„ E = Oxygen absorbed in the effluent in four hours at 80 F.
„ N = Nitric and nitrous nitrogen.
„ V = Volume of sewage in gallons treated per twenty four hours per acre of bed.

Then O

$$= (S - E + \tfrac{2.0}{7} N.) \times 10 V.$$

This formula is intended to give a result which will provide a basis for comparing different methods of treating the same sewage. It is merely a working formula, and has no pretensions to giving absolute results, a much more complicated formula being necessary for this purpose.

24939. Have you any information as to the bacteriological condition of your sewage in dry weather and in storm times?—Some records of bacteriological examinations of our sewage made in dry weather, are as follows:—

			Aerobes per. c.c.	Anerobes per. c.c.
Saltley	Crude	Sewage	873,000	152,000
Rea	„	„	370,000	150,000
Hockley	„	„	121,000	1,000
Aston	„	„	453,000	81,500

Some records of bacteriological examinations of samples of our sewage taken in storm times are as follows:—

			per. c.c.	per. c.c.
Rea	Crude	Sewage	864,000	349,000
Hockley	„	„	476,000	469,000

24940. Are there any chemical poisons in your sewage? If so, what are they, and to what extent do they occur?—There are chemical poisons present in our sewage in the shape of acid wastes and pickle and sulphocyanides. The pickling liquors are present in the largest and most persistent quantities. As much as over 12 parts of iron (F. e.) per 100,000 has been observed in the sewage. The average figure for the iron in our sewage is as follows:—

In suspension 3·29 parts per 100,000
In solution 1·23 „ „

24941. Is your sewage always alkaline?—Our sewage as it enters the tanks has never been observed to be acid, although certain portions of it have approximated to that condition on several occasions, the alkalinity being so low that it was impossible to say definitely whether it was acid or alkaline.

24942. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours duration?—The suspended solids are undoubtedly increased during times of storm. No systematic observations have been made of the quantity of suspended matter present during a storm of some hours duration. The suspended solids have been observed to rise from 38 parts to 380 parts per 100,000 within an hour, owing to a sudden storm.

24943. How many years ago were your sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—Most of the largest main interception sewers were laid between the years 1852 and 1879 and generally speaking are at this date in good condition. In one notable instance, viz., the Rea Main Sewer draining a considerable portion of the city of Birmingham, is at this time being gradually reconstructed owing to insufficient carrying capacity, and has been replaced by a seven feet diameter circular barrel sewer, the discharging capacity of which will be equal to the prospective requirements of the next thirty years. There has not been much sinkage which would admit of deposit of solid matter in the main sewers. Colliery workings do not underlie the surface of the ground in the district.

24944. What is the character of the liquid part of the sewage in storm times? Perhaps you could illustrate this answer by analyses of the liquid portion of the sewage in dry weather and in storm times?—The liquid portion of the sewage during storm times becomes considerably weaker than in dry weather, the amount of dilution depending on the extent of the storm. I hand in a Table of Analyses.

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Storm Sewage.					Dry Weather Sewage.			
Dissolved Solids.	Free & Saline Ammonia.	Chlorine.	Oxygen Absorbed Filtered Sample.	—	Dissolved Solids.	Free & Saline Ammonia.	Chlorine.	Oxygen Absorbed Filtered sample.
97·5	2·418	7·7	7·640	3 typical samples of Saltley sewage.	142·0	2·834	19.5	10·800
117·0	1·649	14·6	9·272		161·5	3·500	12·9	13·764
81·5	2·000	9·2	6·667		137·0	5·167	10·6	16·079
94·5	2·060	14·2	14·390	3 typical samples of Rea sewage.	137·0	2·620	24·5	17·250
82·5	1·550	10·8	10·273		152·5	3·298	30·7	18·682
96·5	2·680	13·8	9·025		169·5	4·572	27·6	20·687
91·0	1·730	11·5	12·230	3 typical samples of Hockley sewage.	138·0	3·850	22·8	17·890
83·0	1·260	12·6	9·160		137·5	2·718	22·6	17·540
87·5	1·431	12.7	11·295		163·5	3·580	28·8	15·199
76·5	1·218	11·0	7·970	3 typical samples of Aston sewage.	140·5	3·670	20·6	14·220
94·0	2·083	13·1	12·229		144·5	3·595	24·4	14·321
66·0	1·425	11·4	9·238		127·0	4·653	16·0	11·610

Note.—Solids separated by filtration.

24945. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think that they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—It will perhaps be best in answering this question to begin by criticising the existing rule of the Local Government Board. The fundamental weakness in this rule as applied in practice, is that the volume and quality of the sewage at the particular time at which the storm occurs is ignored. The actual bulk of sewage flowing down the sewers is very different at different hours of the day. For instance, assuming that the dry weather flow is 24 million gallons per 24 hours, the flow may amount to ½ a million gallons per hour at 6 a.m., and 3 million gallons per hour at 1 p.m. The strength of the sewage for the purposes of this question may be taken as sensibly the same during the whole day. Thence by adopting this cast iron rule with regard to the amount to be treated, *i.e.*, three times the dry weather flow distributed evenly over the whole twenty-four hours, a much greater pollution would ensue if the storm occurred at 1 p.m. than if it occurred at 6 a.m.

Another cardinal weakness in the Local Government Board restrictions is, that local conditions which modify the effects of a storm in a manifold manner are not properly allowed for. Local conditions such as the size and character of the river, quality and quantity of sewage normally dealt with, rainfall of the district, nature of existing works etc., etc., should all be taken into account in deciding this matter.

The establishment of purification works for the *exclusive* treatment of an additional three dilutions of the normal dry weather flow required by the existing Local Government Board standard is in general neither essential nor desirable. The intermittent recurrence of rain does not warrant the provision of expensive works to treat a volume which may only reach the works once in several months, and then only when every stream is in flood.

Storm water filters, *i.e.*, filters for mechanically removing the suspended solids from storm water, are inefficient, their primary cost is high, and the cost of maintenance is considerable. To remove fœtid organic sludge from the surface of a filter without creating nuisance is a practical impossibility, whereas its removal from sedimentation tanks is easy, simple, and, above all, expeditious. Settlement alone in carefully designed tanks would generally be sufficient for the whole flow of sewage and storm-water coming to our works after the first flush of the storm (say after 2 hours), in the case of a storm of some hours' duration.

The addition of chemical precipitants would undoubtedly expedite the deposition of the foul suspended matter brought down in the first period of the storm.

A maximum rate equal to four dilutions of the normal dry weather flow on the present basis ought to be ample (to meet all ordinary contingencies) before passing into the water course.

Some form of standard is necessary, but this standard should be different for different localities, the standard for each place being determined absolutely by local conditions.

24946. What shape and size are your storm overflows ?—The storm overflows are of various sizes. They consist generally speaking of a permanent overflow cill in a free sewer fixed at a level corresponding to a depth of water in the sewer giving a discharge of between six and seven times the average daily dry weather flow.

24947. Would it be possible to have a standard form of overflow, and how would you fix the point at which overflows should be allowed to come into operation ?—It would be possible to have a standard form of overflow. There is no doubt that the usual form of overflow, consisting of a permanent weir cill on a free sewer, such cill being fixed at a level corresponding to the water level of the sewer, when the discharge is equal to a given number of dilutions of the dry weather flow, is most unsatisfactory. It is quite possible with such form of overflow to have a volume passing down the sewer equal to 200 per cent. in excess of the quantity at which the weir comes into operation. The only method of fixing the point at which storm overflows should come into operation seems to be upon the basis of a certain number of dilutions of the dry weather flow, based upon the average daily dry weather flow of sewage. This is, of course, open to the objection that during extremes of dry weather flow the required dilution is not given, but with fixed weirs this is inevitable.

24948. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, etc., and upon the character of the surface soil geologically ?—With a carefully designed storm overflow it is not necessary to make any allowance in respect of configuration of ground with regard to the point at which storm overflows should come into operation.

24949. Should storm overflows be fixed or movable ?—Storm overflows should be adjustable ; main sewers are frequently constructed of sizes which cover the requirements for a period of thirty years in advance of the time of their construction, and should be constructed so that the dilutions may be maintained as the flow of sewage increases from year to year. It is impossible to establish a system of storm overflows which could be movable in the sense of maintaining in time of storm a constant dilution of the sewage with a variable daily flow.

24950. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into the stream should be dependent upon the size and nature of the stream into which the storm sewage would pass ? Is it possible, for example, that in some circumstances no injury to the stream would be caused by allowing overflows to come into operation when the increased flow was slight, while in others this would not be the case ?—The size of the stream into which a storm overflow discharges materially affects the relative pollution effected thereby. This fact is of such considerable importance that it ought to be taken into account. And the diversity of condition so obvious that each case should be judged on its own merits.

24951. What happens to the road water in the portion of your district which is drained on the separate system ?—The outlying suburban portions of the district form the main portions sewered on the separate system, and in those instances the road water is conveyed to the water-courses from the surface water sewers.

24952. Could you give us an analysis of a typical sample of your road water during the early period of a storm?—No examinations of road water have been made.

24953. Then you have no information as to the bacteriological condition of the road water ?—No.

24954. Do you consider that in certain circumstances this liquid should be purified ?—Yes, under certain circumstances, *i.e.*, the first flush of a storm is of such a foul nature that it ought to be purified.

24955. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers ?—The construction of sewers in the drainage area has been left in the hands of constituent authorities incorporated in the Drainage Board. The statistics with regard to this question are not available. In urban districts with large paved areas and dense populations, there might be a combined system only, relief being given by suitable storm water overflows for excessive rainfall. This system is warranted on economical and sanitary considerations. Generally speaking, in suburban and rural districts a separate system is justified.

24956. Is your sewage settled, and, if so, how ? *i.e.*, by quiescent settlement or continuous settlement, and what length of time does it stay in the tanks or take to pass through, as the case may be ? Would you kindly give an average analysis of the tank liquor, including the figures for suspended solids ?—The sewage is settled by means of continuous flow settlement in rectangular tanks worked in parallel. The average time occupied in passing through these tanks is 6¼ hours. The average analyses of the tank liquor for 1904 are as follows :—

Dissolved solid.	Suspended solid.	Free ammonia.	Albuminoid ammonia.	Chlorine.	Nitrates and nitrites as nitrogen.	Oxygen absorbed.	
						Unfiltered.	Filtered.
PRELIMINARY OR GENERAL ROUGHING TANK EFFLUENT.							
107·2	32·2	4·780	1·087	19·3	·935	19·288	12·610
FINAL OR SEPTIC TANK EFFLUENT.							
105·2	19·5	6·121	·887	19·6	·627	15·868	10·071

Note.—Some of these tanks are worked simply as sedimentation tanks whilst others are worked as septic tanks, the first chamber in each tank being used as a grit chamber.

24957. Have you data to show what proportion of the suspended matter in your sewage is settled in ½-hour, 1, 2, 3, 4, 5, 6, 12 and 24 hours, if the sewage is given quiescent settlement ?—The following are the observed rates of settlement with quiescent settlement of Birmingham sewage :—

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Time of settlement in hours.	Rea Sewage. Suspended matter remaining in liquid, in parts per 100,000.		Hockley Sewage. Suspended matter remaining in liquid, in parts per 100,000.	
	Total.	Organic.	Total.	Organic.
0	73·0	43·5	28·0	14·5
½	31·0	18·0	8·5	5 0
1	25·0	14·5	8 0	4·5
2	18·5	10 0	8 5	4·0
3	18·0	10·5	8 0	4·0
4	16·5	9·5	8.0	5·0
5	14·5	7·5	7·5	3·5
6	16·5	10·0	7·5	4 0
7	15·0	8·0	7·5	4·0
8	16·0	9·5	8·0	3·5
9	12·5	7·5	7·5	4·0
10	14·0	9·0	10 0	6·0
11	13·5	8·5	10·5	5·5
12	14 0	8·0	9·0	4·0
24	11·0	6·5	9·5	4 5

24958. What time would be necessary for you to gain a good tank liquor containing, say, no more than 6 or 8 parts of suspended solids per 100,000 from your sewage (without the addition of chemicals), by quiescent settlement, and by continuous flow settlement?—It would be necessary to give the sewage from 8 to 10 hours continuous flow settlement to produce a tank effluent containing about 6 to 8 parts of suspended solids per 100,000. The same result would be achieved by quiescent settlement in rather less time.

24959. Do you prefer to use settlement tanks in series or in parallel?—We prefer to use tanks in parallel.

24960. In the case of continuous flow tanks do you think there is any advantage in the employment of baffling boards or walls?—Baffling boards and walls are of considerable use in a continuous flow tank.

24961. How is the sludging of tanks done at your works, and what is the character of the sludge? Does any nuisance attend the operation, and if so, is it serious? Have you means of storing sludge, or do you have to get rid of it as soon as it is removed from your tanks?—The supernatant water is decanted and pumped off from one tank during the night, the operation lasting about eight to ten hours. The sludge accumulated in the tank generally occupies a space of about 18 inches deep, and is scraped down as rapidly as possible by men with wooden scrapers into the sludge sump connected with each tank. With crude and unsepticised sludge a certain amount of nuisance is inevitable.

The sludge is drawn out from the sump by sludge pumps and forced through a sludge main on to the land for treatment. This operation requires six hours

In its passage from the tank into the suction chamber the sludge is passed through an iron screen with bars $1\frac{1}{4}''$ apart, to which is attached a revolving rake which effectively extracts from the sludge the rags, and similar fibrous material which it contains.

It is found quite practicable by frequently cleaning the tanks to pump a large proportion of road detritus and other heavy material by mixing with the liquid sludge. The remainder which is not capable of being pumped is removed by means of a crane and Priestman grab. There is no means of storing the sludge, which has to be got rid of as it is removed from the tanks.

No nuisance attends the detritus removal operations, as it is immediately buried in adjacent ground.

24962. Should the heavy (road detritus, etc.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge?—It is better to let everything settle, and subsequently screen the sludge. At the same time it is more economical to insert partition walls to separate the maximum amount of road detritus from the rest of the sludge.

24963. What is the manurial value of your sludge, and will farmers take it?—The following shows an average analysis of a number of recent examinations of the dry solids contained in the sludge:—

Analysis of dry sludge.

	per cent.
Organic matter - - -	- 46·55
Inorganic matter - - -	- 53·45
Containing total nitrogen -	- 2·50
Containing phosphoric acid (P_2O_5)	- 1·29

Its manurial value is not large, and the large quantity of water inevitably associated with it does not improve it as a manure. When put on heavy ground it tends to improve the soil by making it more open and free. Farmers at one time took considerable quantities of it, but our own farm bailiffs do not think much of it as a crop raiser.

24964. Are there any chemical poisons in it?—There is no appreciable quantity of what may be called chemical poison in the sludge.

24965. Do you find any nuisance from the treatment of sewage in settlement tanks? Have any complaints been made?—There is no nuisance from the treatment of sewage in settlement tanks. No complaints have been received on this account. There is more smell from settlement tanks, especially whilst cleaning, than from septic tanks.

24966. Have you had experience of the chemical precipitation of sewage?—Yes.

24967. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks?—It is an open question how far the subsequent behaviour of the tank liquor is influenced by the method of removal of the suspended solids. So far as our observations go, no difficulty has been found in the filtration of chemically treated sewage.

24968. Have you tried various chemicals? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage?—Milk of lime, added to the crude sewage, was used as a chemical precipitant for many years, and was totally discontinued in February, 1901. During the last twelve months of this process the tank capacity at the outfall works consisted of two installations of tanks, which were worked in series. The mean period of sedimentation in the preliminary tanks was three and a half hours, and in the secondary installation of tanks the mean period of sedimentation amounted to five and a half hours, giving a total mean period of sedimentation for the limed crude sewage of nine hours. The flow of sewage for the last twelve months of the process was estimated at 20,000,000 gallons per day. The proportion of lime added to the crude sewage was 12 grains per gallon, being equivalent to a quantity of 15 tons 6 cwts. dry lime used daily. The following analysis will indicate the effect of this liming process upon the crude sewage.

During the year 1900, in parts per 100,000.

	Dissolved solids.	Suspended solids.
Crude sewage - - -	129·10	67·60
Preliminary tank effluent	138·00	16·30
Final tank effluent -	133·20	4·20

24969. What is the most effective way of adding chemicals?—The most effective way is to amalgamate thoroughly milk of lime with sewage before it enters the precipitation tank. Our method consisted of shooting milk of lime into the sewer and allowing the mixed lime and sewage to travel some distance together before passing to the tanks.

24970. What is the average analysis of the liquor from your precipitation tanks? What length of time does the sewage remain in the tanks?—The average analysis of the precipitation tank liquor taken over one year was as follows:—

	Dissolved solids.	Suspended solids.	Free ammonia.	Albuminoid ammonia.	Chlorine.	Nitrates and nitrites as nitrogen.	Oxygen absorbed.
Roughing tanks -	138·0	16·3	3·400	1 000	22·9	0·480	10·910
Finishing tanks -	133·2	4·2	3·700	0 970	19·8	0·580	9·520

In the roughing tanks the period of rest was about 3½ hours. In the finishing tanks the period of rest was 5½ hours.

24971. What is the character of the suspended matter in such liquor?—The suspended matter in a tank liquor such as the foregoing is very finely divided, and necessarily of a very light nature.

24972. Do you find it necessary to add further chemicals to the sludge before it can be dealt with?—It was never found necessary to further treat the sludge before pumping it to the land.

24973. What is the manurial value of the sludge obtained by the chemical precipitation of sewage at your works, and will farmers take it? We have no data with regard to the exact manurial value of chemically precipitated sludge at our works. Farmers were in the habit of taking considerable quantities at one time. Our own farm bailiffs did not consider it a very good crop raising manure.

24974. Does it contain any chemical poisons?—The sludge did not contain any large proportion of chemical poison.

24975. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks?—The treatment of sewage *per se* in tanks apart from the sludge question has never been a nuisance, nor have complaints ever been made with regard to it.

24976. As regards septic tanks, how should they be shaped?—The septic tanks in use at present are ordinary rectangular sedimentation tanks. They appear to work very well. We have, however, recently had the opportunity of observing the behaviour of septic sewage in a Dortmund tank. This tank is of the shape of an inverted cone, and our observations indicate that it is very admirably adapted for the septic treatment of sewage, and that it possesses several marked advantages over a rectangular form of tank.

24977. Should septic tanks be divided into sections?—We have no data to show that there is any advantage to be derived from splitting the septic tank up into sections. All septic installations of large size must consist of a number of septic tanks, to facilitate inevitable cleansing operations.

24978. Should they be used in series or in parallel?—Septic tanks should be used in parallel.

24979. Is a scum necessary or desirable?—There appears to be no direct connection between the efficient working of a septic tank, and the presence or absence of a scum. One may be tolerably certain, however, that the tank is working well if a scum is present. It is desirable to conserve heat in sewage and a scum may facilitate this to some extent.

24980. Should the septic tank be closed in, and if so, what advantages does a closed tank possess over an open one?—Our observations of a closed, as compared with an open septic tank extended over a period of six months or so. During that time no appreciable advantage in the use of a closed tank was observed, nor has it been observed that the 8 feet diameter sewer between the precipitation tanks and percolation beds, and which contains a quantity of sewage equal to 6,000,000 gallons, gives relatively better results than the open septic tanks.

24981. What do you consider the best arrangement for the "feed" and "draw off"?—In the Dortmund tank referred to above the "feed" is a large submerged pipe, coinciding with the axis of the cone and discharging vertically downwards, the mouth of the pipe being about 15 feet under surface water level, or about half way down the tank.

The "draw off" consists of a trough running diametrically across the tank to which is attached a scum board dipping into the sewage about 16 inches, this trough gives a weir space of twice the diameter of the tank. From the point of view of a septic tank this seems to be a most admirable arrangement. The tank is 33 feet deep and 44 feet diameter.

24982. At what rate is sewage, as a matter of custom, passed through your septic tanks?—The sewage passes through our septic tanks in about 10 to 12 hours. The septic action is prolonged in the main conduit for about 6 hours more. The mean time occupied by the sewage in passing through the septic tanks is 9·28 hours, varying from a maximum period of 17·8 hours to a minimum of 5·77 hours. The rates of flow which correspond with the above-mentioned periods, expressed in terms of feet per minute, are as follows:—

	Feet per minute
Maximum - - - - - -	0·43
Minimum - - - - - -	0·14
Mean - - - - - - -	0·27

24983. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous? Why do you consider one rate more advantageous than another? Do you think that the rate of flow should depend on the

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strength or character of the particular sewage which is being dealt with?—The actual mean rate of flow through the first set of tanks is ·87 feet per minute, and through the second set of tanks ·32 feet per minute. This rate of flow is sufficient to set up most vigorous fermentation, and results in the destruction of very considerable quantities of organic matter, as evidenced by the copious evolution of gas from the tanks, and by the increase in the amount of "free ammonia" in the tank liquor. A quicker rate of flow is detrimental to the septic action. The action is continued in the large conduit, the liquor taking something like 6 hours to traverse it. At the end of the conduit is a Dortmund tank installation, and here we have been able to make some interesting observations on the behaviour of this already highly septic liquor. We consider that septic treatment of Birmingham sewage for a period of at least 24 hours to be distinctly advantageous. At the present time this is as much as we can say definitely. The observed effect of additional septic treatment at the end of the conduit, in the Dortmund tank is a great increase in the number of micro-organisms in the tank liquor. We consider that the rate of flow should depend very largely on the strength and on the character of the particular sewage to be dealt with—a stronger sewage requiring a longer time, and certain constituents of sewage being more easily broken down than others.

24984. Is it possible to "over-septicise" a sewage, and, if so, for what reasons, and how is the "over-septicising" brought about?—There is reason to think it possible to "over-septicise" a sewage, though the data available on this point are not definite. Moreover, our remarks only refer to very concentrated sewages. Our observations with regard to the possible effect of "over-septicising" were made on a domestic sewage which was being treated on a small double percolation plant. The flow per head was about 7 or 8 gallons per day. The "free ammonia" in the septic liquor was sometimes over twenty-two parts per 100,000, and the "chlorine" over nineteen parts. We could not induce a nitrification figure exceeding 8 parts of nitrogen per 100,000. There was always a considerable reduction in the "albuminoid ammonia" figure in the final bed, but notwithstanding this the "free ammonia" and the "organic nitrogen" in the final effluent remained very high, indicating that the process of oxidation was taking place imperfectly owing to some inhibiting cause. The fault would probably have been remedied by diluting the septic liquor. A highly concentrated sewage which is also highly septicised inclines to give rise to nuisance in warm weather.

24985. What is the amount of digestion in your septic tanks, and how do you calculate this? How far do you find that the digestion is affected by the atmospheric temperature?—We are not in a position at the present time to give reliable figures with regard to the exact amount of digestion that takes place in our septic tasks. We hope, however, to have this information on a more reliable basis shortly. The most reliable figure we can give indicates that the digestion does not exceed 10 per cent. of the dry suspended matter entering the septic tanks. This, however, does not include the preliminary digestion which goes on in our large "roughing tanks"—now used as preliminary septic tanks—nor does it include the digestion going on in the large conduit which conveys sewage from the septic tank proper. These latter figures are not available at present. We calculate the digestion by comparing the "suspended matter" entering and leaving the septic tanks. The digestion is appreciably affected by the atmospheric temperature, being much more vigorous in summer than in winter.

24986. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning, and then remove all the sludge?—In answering that question it will be of some interest to give a brief sketch of the observations which led to the adoption of our present methods.

The tanks were originally designed as precipitation tanks. Lime was added to the sewage in the proportion of about 12 grains per gallon, and the preliminary or "roughing tanks" as well as the final or "finishing tanks" were allowed to run until full of sludge. The former were emptied about once a month and a week was required to empty them, the tanks being only three in number at that time (5 years ago). The "finishing tanks" were emptied about once every three months, and there were 16 of these tanks. The liming operations were stopped in February, 1901, and septic action, which had been put into operation previously in an experimental way, was promoted as far as possible, and no serious alteration was made in this plan till May, 1902. The result of the cessation of liming was a rise in the "suspended solids" in the roughing tank effluent from 16·3 parts per 100,000 in 1900 to 29·6 parts per 100,000 in 1901–02. The "finishing tanks" were now used as septic tanks and the suspended solids in the effluent from these tanks rose from 4·2 parts per 100,000 in 1900 to 25·9 parts per 100,000 in 1901–02. There was a reduction of about 58 per cent. in the *volume* of sludge dealt with, owing to cessation of liming, and adoption of septic treatment.

In June, 1902, two more "roughing tanks" were added to the existing three, and about this time the septic tank capacity was increased by nearly 50 per cent.

As a result of the increase of "roughing tank" capacity, the quantity of sludge dealt with during the period from June, 1902, to March, 1903, rose about 23 per cent. (reckoned per million gallons of sewage treated).

In April, 1903, new pumping plant for raising the sludge was brought into use. By means of it each "roughing tank" could be emptied once a week, instead of once a month, the whole operation being rendered expeditious. This meant virtually a considerable increase in effective tank capacity. More effective sedimentation still was obtained, the sludge removed per million gallons rising during the following year by 44 per cent., while the "suspended solids" in the "roughing tank" effluent fell from 29 parts to 17 parts per 100,000. The "suspended solids" in the septic tank effluent fell during the same period from 23·2 parts to 13·1 parts per 100,000.

A curious phenomenon was now observed in the septic tanks. The quantity of "suspended solids" was much reduced in the liquor being passed into these tanks and yet they began to silt up, whilst their activity as septic tanks was much reduced. This was accounted for as follows. The organisms in our crude sewage are remarkably few in number, such observations as have been made giving an average of 500,000 or so per c.c. The long sojourn of much of the sludge in the "roughing tank" under the old method of emptying (once a month) resulted in much putrefaction with consequent increase in the organic life in the tank liquor. The liquor, therefore, being passed to the septic tanks was in an incipient septic state under the old conditions. Under the quicker methods of sludge removal this incubating ground for the microbes was removed, whilst the organisms already in the septic tanks were deprived of much of the food (sludge) they formerly received.

From May, 1904, to the present time septic action has been promoted as far as possible in the "roughing tanks" by only partially removing the sludge from these tanks (*i.e.* the heavier solids). Also the lighter portion of the sludge which is removed from the "roughing tanks" is pumped into the "septic tanks." By this means the activity of the latter tanks has been completely restored.

A certain amount of sludge should be removed periodically from the septic tanks. The exact length of the period has not finally been settled.

24987. How often would you clean out the septic tank?—During prolonged observations of the behaviour of the sludge, an account of which is given in the foregoing answer, sludge which had been subjected to prolonged digestion in the septic tank possessed hardly any smell, and when pumped on to land might lie exposed for weeks or even months without giving rise to the slightest nuisance. Experiments were made during last summer to deodorize the fresh unsepticised sludge by the addition of chemicals, *e.g.* calcium hypochlorite, but the smell was only partially prevented thereby. The only effective means, therefore, of preventing nuisance by sludging operations, is to septicise the sludge. Moreover, this elimination of smell is far more important in our case than the actual reduction of the bulk of the sludge by septic action. Accordingly we are engaged at the present time in investigating the minimum time which is necessary for deodorizing the sludge in the septic tank. When we have done this we shall leave the sludge in the tank just so long as is necessary to deprive it of smell, and

then remove it, provided the bulk was sufficient to warrant removal.

24988. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—Generally speaking, it will be found to be expedient to remove sludge from a septic tank in fluid form; that is, the density of the sludge might be lowered by the addition of water until the liquid contains not less than 5 and not more than 10 per cent. solid matter. In this form it can be extracted from the tanks through conduits by means of steam pumps, or run by gravitation into a storage tank. In large installations, involving the use of many septic tanks, it will be advisable to extract a proportionate share of the sludge from each of the tanks rather than to remove considerable quantities of sludge from one tank. If possible, the tank should be so shaped that the sludge can be extracted from time to time without running off the liquid contents overlying the sludge. No nuisance need attend this operation.

24989. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank?—There is a tendency for the "suspended" solids in the tank liquor to increase as the tank silts up. After a time, however, a sort of equilibrium is established, and provided that the conditions are kept pretty constant, the "suspended solids" in the septic tank effluent keep fairly constant also.

24990. What amounts of suspended solids, stated in parts per 100,000, are contained in your septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of the period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—At the end of 1903 just after the whole of the septic tanks were cleaned out, the "suspended solids" in the tank effluent fell as low as 4 parts per 100,000: about the middle of 1904 the suspended solids rose to 29 parts per 100,000. The average for the year was 19·5 parts per 100,000.

24991. Should any portion or the whole of the sewage which arrives at the outfall work in storm times be passed through the septic tanks?—There can, in our opinion, be no good purposes served by passing storm waters through septic tanks. The tank may easily be so upset by such procedure as to require some weeks to recover. At the same time septic tanks have been subjected on several occasions to a volume four times the dry weather flow without apparent injury. This, however, only for short periods.

24992. If storm sewage is passed through a septic tank, does this cause an increase in the amount of suspended solids issuing from the tank, and if so, can you give us figures showing what the increase is?—If storm water is passed through a septic tank the suspended solids issuing from the tank are increased. The average for the year in one of the tanks through which storm water passed of necessity, is 29·1 parts per 100,000 of "suspended solids." On several occasions the "suspended solids" rose, owing to storms, to 95·0, 70·0, and again 54·5 parts per 100,000.

24993. May you admit storm sewage to your septic tanks, to an extent which raises the ordinary level of the liquid, without serious detriment to the functions of the tank?—Storm sewage may be admitted, but only to limited extent, to a septic tank, without serious detriment to the functions of that tank.

24994. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way, as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—We have made no observations on the lines suggested.

24995. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in your tank liquor? We have no data on this point.

24996. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor?—Speaking broadly, the impurities in solution in sewage are not materially different from those in a septic tank liquor. The proportions, however, between the relative quantities of the different constituents are undoubtedly considerably modified by the action of the septic tank.

24997. Have you any data on the relative value of plain septic tanks; and septic tanks filled with rough stones or flints?—There was no appreciable difference in the effluent.

24998. Do you find any nuisance from the treatment of sewage in septic tanks?—We find no nuisance from the treatment of sewage in septic tanks.

24999. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered? If so, what do you consider a practicable limit to get down to?—It is desirable that the suspended solids should be removed as far as possible from sewage before it is filtered. The practical limit to get down to is about 8 parts per 100,000.

25000. How do you consider that the removal of suspended solids can best be done?—In view of the fact that the sewage is to be subsequently treated on bacteria beds, the best means of abstracting the solids is simple sedimentation in suitable tanks.

25001. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters?—Dortmund tanks are very efficient in this respect. The average of nearly a year's observations show that 75 per cent. of the solids in suspension in septic tank liquor are abstracted by these tanks.

25002. What other method of dealing with tank liquor before delivering it to filters do you regard as necessary or advisable?—At present, it is not considered necessary or advisable to adopt any other method of dealing with tank liquor before delivering it to the filters.

25003. May I ask you to put before the Commission a full statement of your views as to the comparative cost and relative advantages of the various methods of settlement. I am not sure whether it would be possible for you to make this comparison on the assumption that in each case you reduce the same sewage down to the same figure for suspended solids, but if this could be done it would be useful to include a comparison on this basis. Kindly include the following methods so far as you have had experience of them:—

Quiescent settlement without chemicals.
Quiescent settlement with chemicals.
Continuous flow settlement without chemicals.
Continuous flow settlement with chemicals.
Septic tank treatment.

Quiescent settlement on a practical scale has not been tried at Birmingham.

Continuous flow settlement with chemicals.—This process was in operation here for many years, and eventually abandoned in February 1901. A statement of the cost of the last twelve months treatment is as follows:—

	£	s.	d.
Cost of precipitation and chemicals on an average dry weather flow of 20,000,000 gallons per day	4,332	9	5
Cost of power used in raising sludge from tank and depositing on land 259,512 yards at ·63d. per cubic yard	681	4	5
Materials and labour in tank cleaning at ·571d. per cubic yard	617	8	5
Stanking and trenching into land at 1·6d. per cubic yard	1,730	1	7
8,496 cubic yards of detritus removed from tank by grab at 1s.	424	16	0
Total annual cost of sludge disposal during liming operations at 7·2d. per cubic yard	£7,785	19	10

The result of the continuous flow tank treatment under the method was as follows:—

	Dissolved solids.	Suspended solids.	
Crude sewage	129·1	67·6	parts per 100,000
Tank effluent	138·0	16·3	parts per 100,000

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The period of sedimentation in tanks was 3½ hours. Nuisance frequently occurred in tank cleaning operations, and in subsequent dealing with the sludge on land. The purification effected is shown on the analysis above given, also the annual working cost of the method.

Continuous flow settlement without chemicals.—This process was commenced in February, 1901, and is in practice at the present time. A statement of current expenses incurred by this treatment for twelve months is as follows :—

Year ending 30th April, 1905.

	£ s. d.	£ s. d.
Labour in tank cleaning :—		
Workmen's wages - -	561 11 8	
Clothing, tools, etc. - -	20 0 0	581 11 8
Working expenses of steam plant and attendance :—		
Engineers and stokers -	385 11 8	
Oil, waste, etc. - - -	20 16 0	
Coal - - - - -	557 8 0	963 15 8
Trenching into ground and covering in - - - - -		1,538 1 8
3,932 cub. yds. detritus removed by grab and taken to tip at 1s. per cub. yd. - - - -		196 12 0
Total annual cost of removal and disposal of 203,696 cub. yds. of sludge (equivalent to 3·864d. per yd.) - - - - -		£3,280 1 0
Interest on £10,000 and repayment in 22 years at 3¾ per cent. (equivalent to ·796d. per cub. yd.) - - - - -		£675 11 0

Current expenses -	3·864
Interest and repayment - -	0·796
Total -	4·660

The result of this treatment on tank effluent is as follows :—

	Dissolved solids.	Suspended solids.	
Crude sewage - -	120·2	60·0	parts per 100,000
Preliminary settlement tank - - -	114·7	32·0	
Septic tank - -	112·3	21·0	

The time occupied passing through the tanks was about twelve to thirteen hours. No nuisance has occurred either in tank cleaning or land sludging operations. The purification effected is shown on the analysis given above, and the annual working cost of the system.

25004. As regards continuous or percolating filters, what do you find are the best filtering materials, and what size should the material be ?—We find the following to be very good filtering materials :—

(1) Granite.
(2) Broken bricks.
(3) Selected slag.
(4) Gravel.
(5) Furnace clinker.

They are arranged in order of their merits. Broken brick is a good hard material, but tends to break in the "cracker" into flat particles. Gravel has too smooth a surface, and on this account is not so satisfactory as a support for the organisms growing on it.

The best sizes for materials can only be satisfactorily settled after prolonged and exhaustive tests. As far as our experience goes, the top 9″–12″ should consist of ¾″ to 1¼″ cubes. Immediately underlying this, a layer 12″ deep consisting of ½″ (say) cubes is inserted. The remainder below this should be as near as possible of from 2″ to 3″ cubes.

The larger top layer reduces the tendency of the bed to choke on the surface, whilst the smaller succeeding layer holds the sewage up longer, thereby ensuring better purification. The smaller medium in the upper layers tends also to correct the inequalities in the distribution of the liquid owing to a faulty distributor.

25005. What depth should a percolating bed be to obtain a good effluent ? If this varies with the quality of the liquid going on, or with the size of the filtering material, please state how it varies, what depths you require for different liquids, and how you distinguish one liquid from another, *i.e.* what analytical figures you would rely on for this purpose ?—The minimum depth of a percolating bed which is to produce a good effluent is 5 feet ; our new beds are 6 feet deep. The rate of purification of a foul liquid passing through a bacteria bed is very largely dependent on the length of time the liquid is maintained in intimate contact with the surfaces of the particles of medium in the bed. Consequently from this point of view the medium should be comparatively small in size, and the depth of bed and size of medium are within narrow limits reciprocal quantities. When the medium is reduced beyond a certain point the bed easily chokes and becomes waterlogged.

The "oxygen absorbed" figure is that which would be used for comparison. Only one sewage has been treated on the beds. The following figures show approximate variation :—

Tank Liquor.	Bed A.	Bed E.
9·867	1·833	1·667
6·833	1·367	1·433
12·335	2·632	2·714
10·441	2·132	2·353
14·964	2·014	2·957

25006. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters ?—Yes.

25007. Is the material better disposed of in the form of two beds, to be fed in succession with the same liquid, or in one deep bed ?—On the whole the medium is probably better disposed, *from the point of view of the quality of the effluent alone*, in two beds. There are, however, other extremely important considerations to be remembered in making this comparison.

(*a*) The two shallow beds are more costly to construct than one deep one.

(*b*) The "suspended solids" in the effluent from second shallow bed will not be less than that from the primary bed.

A good effluent can be obtained from filters having a depth of 6 feet. The most important feature is the time the liquid is kept in the bed. The measure of a percolating bed is the volume of liquid which can be put on without washing out the organisms present in the filter apart from the quality of the liquid. It will probably be found that the rate of distribution will be approximately equal for most qualities of liquid, the purification being obtained by regulating the depth of the bed and to a certain degree the size of the medium, but with very small medium, the question of capilliarity becomes an important one, as a large percentage of the air space of a bed may be lost, instancing as an extreme case a bed of sand, which would be entirely waterlogged and choke up in a few days.

In the case of a secondary filter, which deals with liquid partially purified, the elimination of the remaining impurities is much more difficult than the first reduction, and it would seem that the depth of a second filter should be greater than the primary bed.

25008. How should percolating filters be fed ?—Percolating filters should be fed by some device which distributes the liquid uniformly over the surface of the bed. Various types of distributors have been used on our works. Self-propelled distributors are so far unsatisfactory, as the power developed is not sufficient to drive the machines in windy weather. The holes in the arms of the distributor must be of a fairly large diameter. If the number of holes is reduced uneven distribution is the result ; the liquid issues from these holes in the form of a cylindrical column. There is also a considerable amount of wear on the moving parts, which require constant adjustment and renewal.

Cost of distributors per acre of filter, including secondary supply pipes and washout, but not including the main supply pipes to the installation. Nos. 1, 2, 3, and 4 are in units of one-fourth acre and No. 5 in units of one-seventh acre.

—	Distributor per acre.	Supply Pipes per acre.	Washout Pipes per acre.	Total
	£	£	£	£
No. 1. - -	1,320	336	50	1,706
2. - -	640	336	50	1,026
3. - -	640	336	50	1,026
4. - -	2,940	336	—	4,276
5. - -	250	736		986

The revolving distributors are each 120 feet in diameter. This is the largest practicable size for these machines.

The system of spray jets where sufficient head is obtained is much the best. If anything, the cost is slightly less than the other types and the supply of liquor is under perfect control, as the bed is divided into any convenient numbers of distribution units which can each be regulated to distribute any desired volume. Should portions of the bed show a tendency to become waterlogged, the pipes can be washed out without interfering with the remainder of the bays.

There are no working parts to be adjusted or renewed, and with the improved type of jet now used the cleansing of the jets is easily and quickly effected. The distribution is more perfect than the revolving distribution, and the liquid is put on the surface in the form of a fine spray. The cost of improvement is very small, the jets sufficient for one acre, costing from £25 to £30, whereas the distributors Nos. 1, 2, and 4 (which were the first of their respective types) have been vastly improved recently, but it is impossible to take advantage of this without removing the whole of the machine at a cost per acre of some £600, £800 and £2,000 respectively.

25009. Should the feed be intermittent or continuous?—Taking all things into consideration the best results are obtained from a continuous feed, that is continuous during the period the bed is working, but the filter requires periodical rests.

25010. What is the best form of distribution? What, in your opinion, are the conditions which have to be fulfilled by a perfect distributor, having regard not merely to the distribution of the liquid itself, but also to the purification of the liquid and the life of the bed?—One of the best forms of distribution is that obtained by means of a good spray-jet. Certain forms of circular distributors are extremely good, but they are not so invariably reliable.

The conditions which have to be fulfilled by a perfect distributor are the following:—

(1.) Uniform distribution of the liquid on the bed so that each unit of area receives the same quantity of liquid.

(2.) The liquid should be delivered by the distributor in the form of fine rain or drops.

(3.) The distributor should be absolutely under control.

(4.) A reasonable capital cost.

(5.) The less moving or working parts the better.

(6.) The working cost should be as small as possible.

(7.) It should not require a large expenditure of energy to distribute the liquid.

(8.) There is no great advantage in open troughs, as any solids which will not pass the ordinary distributor should not be allowed to lie on the surface of the bed and choke it.

25011. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—It is best to put on the percolating filter a fairly constant amount of liquid. The quantity of liquid may be considerably increased in time of storms of short duration without very seriously impairing the filter. The effluent, however, would probably suffer in consequence.

25012. Is there any practical advantage in artificially heating the liquid which is being treated upon percolating filters?—We have no experience of the effect of artificially heating the liquid which is being treated on a percolation bed.

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25013. Have you had any experience to show whether open sides are an advantage to a percolating filter?—With open sides, somewhat better and brighter effluents are obtained on windy days, and at that time a filter with open sides (if one should be at rest) dries much quicker and better than would be possible if the bed were sunk in the ground. If the site for filters is not naturally such as to settle the question whether the beds are to be above ground, it is not worth while to excavate a large area, simply to enable the filters to be built above ground, but provision should be made at each end of the bed to allow a current of air to pass under the filter as well as enable the floor to be washed out. In a large scheme it will probably be found that it is more economical to clear the whole site, than to leave comparatively small portions of unexcavated ground between the beds; even this ground would have to be opened to receive the supply and effluent pipes.

It is more economical to support the medium by rough retaining walls than to allow the medium to take its natural slope, both in cost and in the large saving of land required for an installation of filters.

Cost of Sloping Medium.

(Per acre of rectangular beds.)

	£	s.	d.
Excavation - - - - -	41	8	2
Concrete - - - - - -	81	9	0
Tiles - - - - - -	91	6	6
Coping - - - - -	19	12	0
Medium - - - - -	247	16	3
	481	11	11
Pipes, etc. - - - - -	19	0	0
	£500	0	0

Cost of Rubble Wall.

(Per acre of rectangular beds.)

	£	s.	d.
Wall - - - - - -	231	0	0
Excavation - - - -	1	15	6
Concrete - - - - -	11	12	6
	£244	8	0

25014. Have you made any study of the conditions of æration of percolating filters?—No.

25015. What do you find is the most convenient superficial area for a percolating filter?—This depends entirely on the shape and configuration of the site available. A large filter is economical and with certain types of distributors, such as spray jets, etc., can be divided into comparatively small units or areas necessary for efficient and economical working.

In the case of filters fitted with revolving distributors, one quarter of an acre is the maximum unit. Distributors can of course be grouped on a large bed, with the resulting loss of area in the portion outside the travel of the arms.

25016. Do you think it desirable that the bottom of a percolating filter be raised from the ground?—Yes. The provision of a false floor and air space beneath a filter is absolutely necessary for mechanical reasons apart from the better æration of the effluent. A false floor provides room for the settlement of sediment formed in the bed, and the bottom layer of medium is not allowed to choke up, as the sediment finds no difficulty, assisted by gravity and the trickle of sewage, in getting to the bottom of the bed. It is obvious that sediment cannot force its way in a lateral direction along the floor of a bed through the intricate passages of the medium. The lower layer of medium is not waterlogged when placed on a false floor, a circulation of air is maintained, and the sediment can easily be washed out. A false floor will result in economy, as it obviates the necessity for taking out the medium periodically for cleansing purposes.

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25017. Do percolating beds, in your experience, choke ? If so, have you been able to measure the rate of choking, and how do you suggest that this choking can be removed, and at what cost ?—To a certain extent, yes. The top layers of media in filters become choked (after about four to six weeks work) with a viscid substance which prevents the water percolating through, and this necessitates giving the filter a rest, the extent varying with the weather, etc. This matter can either be removed by loosening the surface with a fork, or by drying and resting for a time. On restarting the filter a large increase in suspended matter is apparent for a short time, (one or two days,) due to the dried matter being washed through the bed. After flushing out the tile floors the bed becomes as free from obstruction as when it was first started. The cost of thus removing obstruction is but trifling. In one of the beds not provided with a false floor, it was found after twelve months working that the bottom layer of medium was silted up to a depth of from 1¼ inches to 1¾ inches, and after nineteen months work to a depth of from 2 inches to 2¼ inches.

25018. Of what nature are the suspended solids in the filter effluent ? How much is organic matter, and are they putrescible apart from the liquid portion of the effluent ?—The suspended solids in the filter effluent are partly mineral and partly organic. The mineral portion is chiefly very finely divided, consisting in part of fine sand, some of which no doubt is derived from the sewage, and some from the medium of the bed. Much of the mineral matter is hydrated oxide of iron which has been derived from iron in the sewage. We have reason to believe that this iron is thrown out of solution by the action of certain organisms growing in the bed. The organic matter seems to be due to the bodies or organisms, living and dead, which are washed from the bed by the liquid. The sediment contains almost invariably a figure approximating to 30 per cent. of organic matter.

The following description is taken from the laboratory note book :—

General appearance.—This sediment adhered to the floor of the bed in lumps, red worms being embedded in the slimy mass. It is almost black in colour and has a very rank earthy odour when fresh. It becomes foul on standing a few days.

The suspended solids when run on land quickly dry, and do not appear to putrefy, and give off no appreciable odour.

Microscopic appearance.—When a little of the slime is teased out on a slide, it appears to consist chiefly of amorphous matter, partly yellow and partly dark (hydrated oxide of iron). Microscopic filamentous growths of various kinds permeate the mass.

25019. To what extent do you find that the organic matter of the suspended solids issuing in the effluent from a percolating filter is different from the organic matter of the suspended solids going to that filter?—The organic matter present in the " suspended solids " going to the filter is over 58 per cent. of the solid matter. Much of this organic matter represents the residues from the decomposition of organised structures, but it also contains many living organisms, some of which are filaments. The organic matter present in the " suspended solids " issuing in the effluent from a percolating filter seems to consist almost entirely of living and dead organisms and mucilage. It constitutes rather less than a third part of the suspended solids.

25020. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter ? And to what minimum figure do you think such settlement or other final treatment can be carried as a practical measure ?—Experiments have been made on (1) Downward sand filtration ; (2) upward sand filtration ; (3) sedimentation in long shallow trenches ; (4) sedimentation in shallow tanks ; (5) sedimentation in deep tanks.

(1) The suspended solids can be eliminated very successfully by this method, the effluent containing from a trace to about one part per 100,000. It is, however, a costly method, both in capital cost and in working expenses.

(2) A difficulty is experienced in properly cleaning the filter ; it would not be successful on a large scale.

(3) This method removes the bulk of the suspended matter, the effluent containing an average of about five parts per 100,000 ; frequent cleaning is necessary.

(4) This method was not successful, the surface velocity carrying a large proportion of the suspended solids over the weir. By means of a tank which has been called the " Birmingham Separator," the suspended matter may be eliminated at a cost of about 1s. 6d. per million gallons.

25021. Do you find that the suspended solids in your filter effluent vary much in amount from time to time, and if so, can you explain the causes of such variation ?—The suspended solids vary very considerably at times in our filter effluent. We cannot always explain the reason for the variations. We find, however, that whenever a bed has been thrown out of use there is a considerable rise in the suspended solids when the bed is re-started. It often takes the bed several days to return to normal conditions in this respect.

25022. What was the cost of your percolating bed installation per acre, and how much liquid do you treat per acre per 24 hours ? Please give the depth of the filter, and an average analysis of the liquid which you put on, and an average analysis of the effluent when working at the ordinary rate, and when working at a greater rate in storm times. In each case I should like you to give the figures for suspended solids, if you have them ?—The cost per acre of the Birmingham filters for a complete installation of 15 acres, including main supply and effluent conduits, etc., but not including land, is £6,300 per acre. The volume treated per acre is 750,000 gallons per day. The depth of the filter is 6 feet.

N.B.—Great stress is laid on the fact that the quality of the medium put in the bed very materially influences the cost. In the beds referred to above every precaution has been taken to ensure that the medium is of a permanent character. If an inferior and cheaper quality of medium is used the inevitable expense due to subsequent breaking down, replacement, etc., will rapidly bring the cost up to that of the better class material. Also when the medium gives trouble the bed has to be frequently thrown out of use, thereby rendering the bed useless for considerable periods.

25023. Have you made any experiments which throw light on the action of percolating filters, with regard to the oxidation of the ammoniacal and organic matter in solution, and the organic matter in suspension ?—With regard to the ammoniacal and organic matter in solution, no direct experiments have been made to throw light on these points. It has been observed, however, that with very efficient aeration the first action is oxidation of the ammonia with comparatively little action on the organic matter. When the aeration is less efficient, and the sojourn of the liquor in the bed prolonged, *i.e.*, by use of smaller sized medium, a lower nitrification with greater elimination of gaseous nitrogen and reduction of dissolved organic matter takes place.

As our beds are usually constructed, the organic matter in suspension appears to be retained in the upper layer of the bed, that is in the first 15 inches. The medium in this upper layer is in most of the beds of smaller size than that lower down in the bed. The particles of medium becomes thickly coated with a layer of black matter in which putrefaction, rather than direct oxidation, would seem to predominate. Probably the action going on here is of the nature of symbiosis. There is a sharp dividing line between the layer and the brown medium (the colour being no doubt due to ferric hydrate) immediately below it, and this is the normal condition of a healthy bed.

25024. Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter, or that they are first absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one ?—From observations on filters generally, we incline to the view that the capacity of a filter for abstracting dissolved matters from the liquid passed through it is very largely, if not entirely, a function of the proportion of medium surface presented to the liquid. For instance, in large medium with a small quantity of liquid a high degree of oxidation is obtained, but if the quantity of liquid is increased the amount of change taking place in the dissolved matters falls off very rapidly. As the medium is reduced in size the rate at which liquid can be put on the bed may be increased to a much greater extent before the effluent

shows the same amount of unaltered constituents as in the larger medium with less liquid. This was exemplified very markedly in the case of a ¼-acre bed where the medium in one half (on one side) of the bed consisted of particles twice as large as in the other half. The smaller medium gave the best effluent.

25025. Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter ?—The ordinary changes of temperature do not appear to affect the filters in a measurable degree, but in winter the purification appears to be less than in warmer weather. In very severe weather ice forms on portions of the beds, but has not except in the case of a rotary distributor been sufficient to stop the working of the filters, and even this was due to an exceptional frost of 21 degrees.

25026. Have you found any trouble from vegetable growths in percolating filters ? If so, have you been able to form any opinion as to the causes of these growths, and as to the way in which the growths can be prevented ? —On the surface of some of the percolating filters, vegetable growths of the nature of cladothrix give some trouble by choking the surface of the medium. This can be prevented to a certain extent by forking over the bed.

25027. Do you find any nuisance from the treatment of sewage on percolating filters ? Have any complaints been made ?—There has been no nuisance, and no complaints have been made.

25028. Would you kindly compare the cost (initial expenditure and annual upkeep and working), and relative advantages of percolating filters and contact beds. Do you consider that one form is best for some kinds of sewage, and the other form for other kinds of sewage ?—The first bacterial filters with which experiments were conducted here were " contact " beds. These were observed to choke up or lose their water-holding capacity so rapidly that it was apparent that a serious item in the cost of upkeep would be the expense of washing the medium. Several beds were then constructed as percolation filters. Provided that a false floor was constructed so that the bottom of the bed was kept free and open, the percolation filter never choked up. Also the percolating filter was capable of taking much more water per square yard, than the contact bed, and the area occupied by the percolating plant would be thereby correspondingly reduced. One of the most noteworthy differences between contact beds and percolating filters is that the former seem to retain more solid matter in the bed, and therefore choke up, whilst the latter do not retain the solid matter, and provided that the bed has a false floor will not choke up. One percolation bed which has been working almost without a stop for 1 year and 9 months has been opened up by us quite recently down to the floor of the bed, and the medium was found to be even cleaner (free from dust) than when it was put in. There is, of course, more suspended matter in the percolation bed effluent than in the contact bed effluent. As far as cost of upkeep goes it resolves itself into comparing the annual cost of cleaning and renewing the medium from a contact bed with the cost of removing the suspended matter from a percolation bed effluent.

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A greater loss of total combined nitrogen takes place normally in a contact bed as compared with a percolation bed. This is in favour of the contact bed. On account of this latter fact a highly nitrogenous sewage would be best treated in a contact bed. In fact it has been observed that in a sewage containing nitrogen largely in the form of sulphocyanides the loss in nitrogen was greater on contact beds than on percolation beds.

25029. Do you find that the chance of nuisance is any greater with one form of filter than with another ? Does the risk of nuisance depend on the kind of sewage which is being treated, or on the nature of the preliminary treatment to which the sewage has been subjected ?—Certain forms of distribution, viz., the spray jet which delivers the liquor in the form of fine rain, gives off more smell than those delivering the liquid in sheets or columns. Such smell does not, however, amount to a nuisance. Septic sewage generally gives off less objectionable smell than non-septic sewage. During the first summer that septic sewage was applied to the farm lands here residents asserted that the smell observable was very greatly reduced thereby. Our own observations confirm this.

In the case of sludge which has not been subjected to septic treatment the smell is most offensive, whereas in the case of septicised sludge the objectionable odour is conspicuous by its absence.

25030. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor or tank liquors could be satisfactorily purified on a percolating filter, and how many gallons per cubic yard on a contact bed ? If so, would you kindly state the results, at the same time telling us in precise terms what was the composition of your tank liquor or tank liquors, and what you are considering to be a satisfactory effluent ?—There are no reliable records to hand of the exact quantity of liquid being treated on our contact beds.

On percolation filters 60 gallons per cubic yard of tank liquor is being treated per 24 hours with the following results:—

TANK LIQUOR.

Dissolved Solid.	Suspended Solid.		Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Oxygen Absorbed.	
	Total.	Organic.				Unfiltered.	Filtered.
94·6	8·1	4·7	6·677	·547	19·5	12·006	8·510

PERCOLATION BED EFFLUENT.

Dissolved Solid.	Suspended Solid.		Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates and Nitrites as Nitrogen.	Oxygen Absorbed.	
	Total.	Organic.					Unfiltered.	Filtered.
107·5	4·6	2·3	·976	·162	17·7	3·359	1·620	—

This effluent from the percolation filter is considered *highly* satisfactory.

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25031. Could you express an opinion as to how the number of gallons would vary with variations in the strength of your tank liquor, and on what figure or figures you would rely for defining the "strength" ?—The quantity of liquid treated on the bed would vary within narrow limits and approximately with the "strength" of the tank liquor. The figures on which most reliance would be placed in defining the tank liquor would be those for the "Albuminoid Ammonia" and the "Oxygen absorbed," more frequently the latter.

The following figures for "oxygen absorbed" illustate the variations in the tank liquor and effluent respectively :—

Silt tank liquor.	Effluent Bed A.	Volume treated on Bed A in gallons per sq. yard per day.	Effluent Bed E.	Volume treated in Bed E in galls. per sq. yard per day.
11·556	1·722	59	2·000	79
15·761	1·957	59	1·848	79
12·772	2·022	59	1·782	79
9·005	1·556	59	1·430	79
11·709	1·990	59	1·709	90
13·384	1·663	59	2·051	90
13·577	2·056	59	1·833	90
11·450	2·250	59	2·500	90

25032. Have you had any experience of storm water filters ?—In 1901 an installation of No. 8 Storm Water Filters, each half an acre in area, containing three feet of screened gas coke, were constructed and brought into use at our Saltley Outfall Works. They have been regularly in use for the last four years. As the result of this experience it may be said that the purification effected is most irregular and quite negligible in proportion to the cost incurred. The storm water, previous to being passed into the filters, is passed through sedimentation tanks in conjunction with the sewage which is treated thoroughly. The surface of the coke becomes rapidly choked, and unless they are frequently cleaned or forked over it is impossible to retain them in working condition, and even when this is effected the effluent which first comes from the filters after a period of rest is generally foul.

25033. Do you consider storm water filters lose any of their efficiency by being used only intermittently at long intervals ?—If the efficiency of storm water filters is assumed to depend on their biological condition, then most decidedly they lose by being used intermittently at long intervals. If, however, as is more probable, their efficiency depends on their power of mechanically abstracting the suspended matters from the storm water, then they do not lose by long rests.

25034. Have you any practical suggestions to make for disposing of sludges, *i.e.* :—(*a*) sewage screenings : (*b*) material from detritus tanks : (*c*) sludge from precipitation tanks : (*d*) sludge from septic tanks : (*e*) sludge from settlement tanks ?—

(*a*) *Sewage Screenings.*—The operation of screening sewage beyond the point when materials are eliminated which will choke or otherwise interfere with the proper working of suction pipes and other sewage plant, is to be deprecated. It is generally more economical to screen the sludge as it is being pumped from the tank than to screen the crude sewage. These sludge screenings are tipped on a spoil bank and buried. Where we have screening plant for the sewage, the screenings are disposed of by tipping on adjoining vacant ground, from which they are subsequently removed by our farmers for manuring purposes. Otherwise the screenings should be drained rapidly, and within twenty-four hours either burned in a furnace or covered over with soil.

(*b*) *Material from detritus tanks.*—Our experience shows that the heavy detritus and grit invariably carries down with it a large proportion of organic matter. Analyses have shown it to frequently contain 45 per cent. of organic matter. The heavier portion of the grit, containing about 50 per cent. of water, can be rapidly removed by a grab attached to a steam crane, into spoil tip wagons, and thereby on to a spoil tip. As it becomes offensive on exposure for a few days, it is covered over with soil within two hours of its deposition. This matter amounts to an average of ·46 cubic yards per million gallons of sewage (dry weather). It is practicable to dispose of the bulk of the grit by working it in with the tank sludge which is pumped to the land. Its presence in the sludge is desirable, as it improves heavy land.

(*c*) *Sludge from precipitation tanks.*—Chemically precipitated sludge is generally offensive, and gives rise to much objectionable smell in the vicinity of the tanks during the cleaning and emptying operations. The sludge from such tanks should be removed frequently, rapidly, and systematically, and remain exposed to the air as short a time as possible, whether in the tanks or on the land. The sludge is pumped into trenches on the land, and is covered in with soil as expeditiously as possible. Some five or six years ago it was the practice to pump such sludge into shallow lagoons, thereby causing a large surface of the sludge to be exposed for considerable periods. The nuisance caused at that time was consequently very great. In all these operations perturbation should be reduced to a minimum.

(*d*) *Sludge from septic tanks.*—If sludge has been subjected to digestion in septic tanks for a sufficiently long period, it loses its characteristic pungent and offensive odour. It may be either pumped into trenches as indicated above, or even put on the surface of land and exposed to the air till dry, without giving rise to smell ; when thus treated it rapidly settles down in bulk, and as it dries the surface cracks up. In the course of a few months it assumes the appearance of a rich black soil.

An analysis of this sludge gave the following results :—

	per cent.
Total organic matter in dry sludge	44·67
Total organic nitrogen in dry sludge	2·47
Siliceous matter (sand, etc.)	20·00
Oxide of copper	1·71
Oxide of iron and aluminium	20·00
Other metallic oxides (about)	12·00
Oxides of phosphorus and alkalies (about)	2·00

(*e*) *Sludge from settlement tanks.*—The remarks under section (*c*) above apply to this sludge also.

25035. Do you find that some methods of disposing of sludge are more likely to cause nuisance than others ?—Yes. The sludge from precipitation and settlement tanks when disposed of on land in flat lagoons gives rise to great nuisance. Our present method of putting the sludge into trenches and covering in quickly has reduced the nuisance very greatly. Again it has been found that after the first dose of crude sludge has been put in the trenches, if a dose of well digested septic sludge is put on top of it, the nuisance is thereby prevented.

25036. What, in your opinion, constitutes a good effluent ?—A good effluent should satisfy the following conditions :—

(1) It should be non-putrescible.

(2) It should not contain much dissolved organic matter, *i.e.*, the "albuminoid ammonia" figure should not exceed ·20 parts per 100,000, and the "oxygen absorbed in four hours" figure should not exceed 2·00 parts per 100,000. N.B.—An effluent may contain considerable quantities of organic impurity and still be non-putrescible owing to the large quantity of available oxygen also present in the form of nitrates, etc. The objection to such an effluent lies in the fact that it usually furnishes an excellent pabulum for the growth of organisms of various kinds.

(3) It should not absorb "dissolved oxygen" at an excessive rate.

(4) The mineral suspended matter in such an effluent should not exceed 1 to 1·5 parts per 100,000, and the organic suspended matter should not exceed 1·0 to 1·5 parts per 100,000.

(5) On standing for, say, one day, the clarified effluent ought not to deposit more than 1 to 2 parts per 100,000 of solids from solution.

25037. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter ?—A bacteria bed ought to be viewed as an engine of destruction. That is to say, that although its primary function is to render the liquor passed through it innocuous, it ought to do this preferably by eliminating as far as possible the objectionable constituents of the sewage, and not merely by fixing them in the liquid in a mineralised form. For instance, the nitrogen of organic matter ought to be converted as far as possible into gaseous nitrogen, and not into nitrate. The nature of the conditions in a contact bed are such as to favour this reaction to the exclusion of any other, *i.e.* the freedom of its action is very limited. However, not the least of the advantages possessed by a percolation system is the large degree of latitude permissible in the construction of the filter, *i.e.*, it is a matter of comparative ease to construct the bed so as to produce any desired result. For instance, a land filter is a percolation filter, and it is not possible to produce a better effluent by any means practicable than the effluent from a well-managed plot of suitable land. In constructing a percolation filter, therefore, one should aim at ensuring the production of an effluent approximately to this, without materially sacrificing the advantages of the percolation filter *per se*. In other words, if it is considered desirable there is no reason why the effluent from a percolation filter should be materially different from the effluent from a contact bed.

25038. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons ?—We rely on the following tests chiefly: (1) Suspended solids; (2) albuminoid ammonia; (3) oxygen absorbed; (4) three minutes test before and after incubation; (5) nitrification. The suspended solids are obviously objectionable, and the nitrification indicates the conditions obtaining in the filter from which the effluent has come. The tests (2) and (3) indicate the proportion of organic matter, and test (4) indicates the general behaviour of the effluent.

25039. Have you tried the "aeration" test, *i.e.* the rate at which dissolved oxygen is taken up by an effluent ?—We have tried the "aeration" test. We consider it a most excellent test as the information it furnishes is most useful. It is, unfortunately, not sufficiently rapid to be generally applicable.

25040. Is one standard for all effluents passing into non-potable streams possible and desirable, and if so, what should it be ?—One standard for all effluents passing into a non-potable stream is neither possible nor desirable. We could instance cases of sewages or tank liquors which are quite foul, being better from point of view of merely analytical figures than some effluents which are non-putrescible.

25041. If a general standard is not possible, should there be more than one standard, and if so, how should a plurality or series of standards be formulated. What amount of suspended matter would you allow in an effluent, and what are your reasons ?—The standard applied in any particular case ought to be formulated after thorough consideration of all the local conditions, *i.e.* the "strength" of the sewage, the size and nature of the stream into which the effluent is discharged, the uses to which the water of the stream is subsequently put, etc. etc., ought to be considered in applying a standard.

We would allow about 3 parts per 100,000 of suspended solids in an effluent. Such a quantity of suspended solids does not give rise to any trouble in a stream.

25042. Have you made any systematic observations as to the effects of discharging effluents of known volume and known composition into ditches, canals, brooks or rivers of approximately known volume ? The main points referred to here are:—(*a*) Nuisance from smell; (*b*) De-oxygenation of water; (*c*) Encouragement of vegetable growths either of the nature of sewage fungus or of green weeds; (*d*) Damage to fish ?—Our effluents discharge into a water course which we have every means of observing with regard to the general effect thereon. Our observations are as follows:—

(*a*) *Nuisance from smell.*—No nuisance arises from the river in this respect. Near the water in certain states of the atmosphere, *e.g.* when the air approaches saturation point with aqueous vapour, a peculiar rank odour has been observed.

(*b*) *De-oxygenation of the water.*—We have made a number of observations on this point. The water of the river below our works and lands contains about the same quantity of "dissolved oxygen" as the water of the river above our works, *i.e.* about 5 c.c. per litre at 6°C. The rate of absorption of "dissolved oxygen" is, however, higher below the works than above them. The effluents themselves show a high percentage of "dissolved oxygen" (*i.e.* from about 4 c.c. to 6·2 c.c. per litre at 6°C.) during cold weather, but the amount is somewhat lower in warm weather. The variation may be said to depend roughly upon the atmospheric temperature, and points to the increase of biological activity as the cause of the lower figure in warm weather.

(*c*) *Encouragement of vegetable growths either of the nature of sewage fungus or of green weeds.*—Vegetable growths of the kind usually spoken of as "sewage fungus" grow most luxuriantly in our effluents and one or two of the effluents admit the growth of algæ, these latter being the best aerated, and correspondingly most highly nitrified, of the effluents. The effluents generally however, may be said to favour the first class of growth to the exclusion more or less of the latter. We have examined these growths, and to a limited extent studied their behaviour. They are a mixture of filamentous plants, the thickness of the filaments being of microscopic dimensions, but growing in a most luxuriant manner. They probably belong to the genera cladothrin Leptothrix, Crenothrix, etc. Their presence is intimately associated with the presence of iron, and this no doubt accounts for their absence from well aerated colourless effluents. The slimy mass in which they grow is coloured brown when fresh, and goes black on keeping owing to the iron present. As far as our observations go, these growths do not seem to flourish in the river. The conditions there are evidently unfavourable to their growth, and the above description suggests a reason as to why the conditions are not favourable.

(*d*) *Damage to Fish.*—We have not made systematic observations with regard to the effect of our effluents on fish.

25043. Could you make a short statement, setting forth the values you attach to the different chemical tests in use for determining the qualities or conditions of sewages and effluents, and giving your reasons ?—The "Dissolved Solids" estimation is of some importance in several respects. The dissolved constituents naturally undergo considerable modification during the process of treatment, and we have found this estimation a very useful and rapid check on the general method of purification. Abnormal conditions of sewage or effluent are often readily indicated thereby. Also the nature of the residues is occasionally of considerable interest.

The importance of the "suspended solids" test cannot well be over estimated, for reasons which have been previously indicated. The proportion of organic matter in these solids is a very important estimation.

The "free ammonia" estimation is of interest in a sewage, as indicating either the history or condition of the sewage, *i.e.*, if the sewage is a normal one, as to whether it is old or fresh, or if this figure is low it may indicate the presence of antiseptics in the sewage. We have found this exemplified very frequently. A high "Free Ammonia" in an effluent invariably indicates that the process of purification has not been completed, that aëration is deficient, for instance. The field or filter from which such an effluent is derived is usually found to be waterlogged, or the sewage has passed through the filter too quickly, or, again, that the sewage is over-septicised.

The "Albuminoid Ammonia" figure is a most important one. It gives a very reliable indication as to the relative efficiency of different methods of treating the same sewage. Also as a control of any particular field or filter this figure is invaluable, providing that the effects of normal conditions are fairly well known. We have examined sewage effluents where the "Albuminoid Ammonia" figure alone was not a safe guide to the amount of nitrogenous organic matter present, but for the same sewage under known conditions it is a most excellent comparative test.

We have partly indicated in a previous answer our views with regard to the nitrification test. A high nitrification in an effluent invariably indicates good aëration in the filter, but it does not necessarily imply a good

effluent. In fact, we have observed on a number of occasions that fairly good nitrification may be obtained whilst the liquor is otherwise very little changed. Under these conditions, however, a high proportion of nitrite is produced.

The "Oxygen absorbed in 4 hours at 80 F." is perhaps the most useful test in vogue for the examination of sewages and effluents. In the case of manufacturing sewages, however, its value is often modified by the presence of highly oxidisible constituents of the sewage. Cases have come under our notice where bodies such as sulphocyanides pass through the sewage plant to a considerable extent unchanged. Account must be taken of such bodies, as well as of the presence of much nitrite in an effluent, when judging of the efficiency of any particular works or the quality of any particular effluent.

The "3 minutes test" is a ready means of determining the putrescibility of a liquid, when applied before and after the liquid has been incubated. It is essential that a means of determining the tendency of a liquid to putrify be at hand, and this test is correspondingly important.

25044. What are your views with regard to the quantitative determination of the "strength" of a sewage, tank liquor, etc. ?—The determination of the "strength" of sewage, tank liquor, etc., in precise terms is of considerable importance. It is at least highly desirable, if not absolutely essential, in order to get an idea of the efficiency of a particular method of treatment or of the plant or portions of plant used for the treatment.

In absolute terms the "strength" is represented by the amount of oxygen necessary to completely oxidise the organic impurities in a given unit of volume of the liquid under consideration. For practical purposes the "strength" may be measured by a comparison of the "oxygen absorbed" figure in the liquid under consideration with that of the corresponding figure in an admittedly good effluent.

An attempt has been made to get out a method which can be applied in practice for comparative purposes of measuring the work done in purifying a given liquid. It is hoped that when further experimental information has been obtained by us, that a formula will be produced which will not necessarily be a means of comparing the work done in purifying different sewages but will give a "comparative efficiency co-efficient" for any particular method, as applied to a given sewage.

25044*. If there are any further points on which you would wish to speak we should be glad to hear your views on them.—The questions which have been put to us will have a most excellent effect, if conscientiously answered. They might with considerable advantage be sent round periodically to the various authorities concerned. Then comparison of the answers given at successive periods, as experience accumulates, ought to yield valuable information.

25045. With regard to the question of the reception of trade effluents into your sewers, have you any idea as to what ought to be done in the event of a dispute between traders and the local authority ?—We have had no difficulty, my Lord, about that. Traders have been, in our experience, very reasonable, and my board has been very unwilling to do anything which would militate against the trades of the district so long as we find that it is possible to treat on biological methods the sewage at no great cost.

25046. They have never considered what would be the most satisfactory way of settling a dispute if any should arise ?—No, we have had no occasion to consider that.

25047. On Question 24939, am I right in inferring from the figures that you have given there that the storm sewage is sometimes more polluted than the dry weather sewage as regards the organisms to be found in it ?—(*Mr. O'Shaughnessy*) Yes, my Lord, generally speaking, as you see from the figures there; the first lot of four figures represents the fairly normal dry weather conditions.

25048. On Question 24976, you say that the tank in the shape of an inverted cone possesses several marked advantages over a rectangular form of tank. Well, now, could you specify those advantages ?—Yes, the advantage is not merely in the shape of the tank itself *per se*; but in the method of delivery, which is an essential part of the arrangement. In the tank in question the sewage is delivered from a pipe vertically downwards, the pipe coinciding with the axis of that cone. The essential advantage of the tank from the point of view of its being used as a septic tank is in the fact that a relatively large surface is exposed for the reception of the lighter organic sludge; inevitably from the shape of the tank the flow of the sewage is continually diminishing as it ascends. The result is that the suspended matter is differentiated according to its density; that is, the heavier matter falls out first. The mineral matter may be said practically invariably to be of greater density than the organic matter; consequently you get the mineral matter accumulated at the bottom of your tank, which is periodically flushed out. The lighter organic matter is then distributed in zones over a large conical area of the tank and is distributed in thin layers in contact with the liquid; and, therefore, giving a maximum amount of advantage in being subjected to septic action; that is the essential thing in regard to that.

25049. Then if you will take the next question, 24986, you say that the organisms in your sewage are remarkably few in number ?—Yes.

25050. Do you attribute that to the effects of your trade refuse ?—Quite so, it is the only thing we can attribute it to.

25051. Well, then in Question 24989, you say, "After a time a sort of equilibrium is established, and provided that the conditions are kept pretty constant, . . ." Well, now, how can you keep the conditions pretty constant, because the suspended solids that are coming in are always coming in in increasing numbers ?—Yes; but with regard to the septic tanks, we have, between the sewers and the septic tanks proper, a screen of preliminary tanks, which tend to tone down the inequalities immensely; that, in working septic tanks, ought to be a *sine qua non*.

25052. In the following question you tell us that the suspended solids at one time fell as low as four parts per 100,000, and that the average for the year was 19·5 parts per 100,000; can you tell us the maximum ?—Unfortunately the maximum was omitted by a clerical error; it amounted to 29 parts per 100,000 about the middle of the year.

25053. On question 25003; the question of cost. Taking the tank treatment by itself, the septic tank seems to be clearly cheaper than the precipitation, but the effluent from the septic tank carries forward a much larger proportion of the suspended solids; and it would seem to follow from that that the cost of maintaining the filters fed by this effluent would be greater. Can you say whether the saving on tank treatment in such a case would be greater or less than the extra cost of maintaining the filters ?—(*Mr. Watson.*) We are dealing in this case with Birmingham; we have a very large area of ground on which we distribute the septic liquor. It is no disadvantage but rather an advantage to us to have the suspended matter run over the land. Then before we take the sewage on to our percolating beds we have got silt tanks, which we have called for lucidity, Dortmund tanks; they are not exactly Dortmund tanks, but they are after the form which was originally constructed at Dortmund. There we take out 75 per cent. of the solids before the liquor is put on to the bacteria beds, and in any future bacteria beds which we build that form will probably be adhered to.

25054. On question 25005 were the beds "A" and "E" of the same depth and similar construction ?—They are not; bed "A" is a slag bed, seven feet deep, and bed "E" is an ashes and clinker bed six feet deep; the one has the liquor distributed over it by means of a rotary distributor, and the other has fixed spray jets; these are the two main differences between the two beds.

25055-6. And in the same question it strikes me as rather curious that your experience is that the elimination of the remaining impurities in the second filter is much more difficult than the first reduction in the first filter. Have you made many observations on that point ?—Yes, my Lord, we think that that almost goes without saying, because the more suspended matter you have, one particle assists the other in precipitating its neighbour to the bottom; consequently, you will have a bigger percentage of elimination of suspended solids if you started with a large amount of them, than you will have if you started with a small amount.

25057. On question 25022, the cost per acre; do you include the distributor in that cost ?—Yes, my Lord, everything but land is included in that answer.

25058. On question 24928, you give us the amount of the sewage and storm water that come to your outfall works; but you say you have no records of the volume which passes over your storm overflow?—That is so.

25059. Although you have no record, have you any sort of approximate idea of how much it might be?—No, I am afraid I could not very well venture to answer that question; we have only within the last four months put down self recorder gauges. In a year's time we will be able to give some definite information on that point, meantime we cannot.

25060. (*Sir William Ramsay.*) In Question 24915, you state "that about three-eighths of the total rainfall would pass into the surface or storm water sewers, and the remaining five-eighths would pass through the foul water system of sewers." How has that been arrived at; upon what sort of data do you base that conclusion?—From actual measurement. We have two of our suburban districts completely separated and we have been able to find from records made that the figures given here are correct.

25061. That is very satisfactory. In answer to Question 24925 the last sentence runs, "the variation between maximum and minimum rate of dry weather flow in the sewers on which overflows are placed is estimated not to exceed a variation of four to one." Does that mean that you may have four times as much flow at one time than another?—Yes.

25062. It has nothing whatever to do with the overflows, has it?—No, not that one.

25063. In answer to Question 24931, under heading (*a*), you say that, "it is understood that 75 per cent. of the total suspended solids in liquid trades wastes shall be eliminated before the liquid is admitted into the sewers"?—Yes.

25064. Is that irrespective of the total amount of suspended solids?—No.

25065. Does it mean that of the suspended?—It means that of the suspended solids we expect manufacturers to eliminate 75 per cent. of them before they send the liquid into the sewers.

25066. How does that work, is it satisfactory?—Well, we do not have very many cases; we have only recently brought that into force; we have been dealing chiefly with paper works.

25067. But have they no difficulty of getting rid of 75 per cent. of their suspended solids?—They are supposed to take the solid material away and put it wherever they like; we do not want it put into our sewers.

25068. Have you a penalty, or is it merely a question of arrangement?—Well, we have not had occasion to enforce that. We have a case pending at the present time and it may result in litigation, but up till now we have not had a case.

25069. I suppose, in your answer to Question 24933, the average of 71·9 suspended matter remains pretty constant; it does not fluctuate as is shown in the highest and lowest observed figures?—(*Mr. O'Shaughnessy.*) Well, we have amended that answer by putting an additional note in to the effect that these are quite exceptional figures; of course it answers the question just as it is put, but there are several other cases where we have had it between 300 and 400 but those do not occur very frequently.

25070. On the whole it is pretty nearly 75?—On the whole it fluctuates between 70 and 80.

25071. That would be the answer to the question I think?—That would be the answer to the question.

25072. Then in 24935 there is a surprising amount of nitrates in the sewage; is that owing to nitric acid being turned into the sewers?—Yes, that is so; it comes from jewellers' operations.

25074. I should like to ask as regards 24938, what is "oxygen conferred on sewage"; it is a very odd expression?—It is quite a novel expression, "oxygen conferred on sewage in pounds per day" would be the full thing; that means to say, if you have a bacteria bed which, say, is treating 1,000,000 gallons of sewage per day, you are passing, say, 10,000,000 pounds of water approximately through that bed. Then, in order to produce a given purification you will have to confer on the sewage a certain amount of oxygen which will depend very largely on the strength of the sewage.

25075. Yes?—The idea which is conveyed by oxygen conferred on sewage per day is an analogous one to expressing mechanical energy as in horse power, for instance.

25076. That is perfectly right, but I do not see how you are going to find it out; is it done by permanganate titration before and after?—No, there is no pretence to it being an absolute formula; it is merely a sort of working formula, to compare, if possible, as far as it can be done the work done on different sewages.

25077. Yes, I quite see that; but what I want to understand is by what chemical process do you make the estimate?—Oh, the oxygen absorbed.

25078. The permanganate oxygen absorbed?—The permanganate oxygen absorbed plus the oxygen in the nitrate.

25080. In 24945, towards the end, you say, that "a maximum rate equal to four dilutions of the normal dry weather flow on the present basis ought to be ample (to meet all ordinary contingencies) before passing into water course." Is that based on experience, or is it a pious opinion?—(*Mr. Watson.*) Four dilutions?

25081. Four dilutions?—No; what I have aimed at, sir, is this, I think that it is quite right and proper that there should be storm water weirs to allow six times the dry weather flow to pass down the sewers towards the outfall works; and that the remaining quantity which comes in time of storm should go right to the water courses; but I think that it is not right that we should have to treat so much as six times the dry weather flow at our works. I want to direct attention to the expression four dilutions. I have used that expression because I think you have it in the question in referring to the Local Government Board rule, but I really mean four times the dry weather flow. If that is what is meant in the front then that is right; you see our area is a very large one; it is ninety square miles, and although you might have at one part of your district a quantity of water coming down any particular sewer it might not be perceptible on our works.

25082. I see, the rainfall would be local?—And when the rainfall is general, when there is a very large rainfall all over the ninety-two square miles, we invariably find that the river at that time is several feet above its normal level; consequently, I am inclined to the view that we are more or less wasting public money in treating such a very large body of sewage as this implies.

25083. Yes, quite; the ninety square miles surely means a great deal more than the space covered by the City of Birmingham?—Oh, yes; if you look on the first page you will find that we include Birmingham, the Borough of Aston Manor, and so forth.

25084. I see, and so forth; which are very largely uninhabited lands?—Oh, by no means; the Borough of Aston Manor is the most populous district barring Shoreditch in this country.

25085. To complete the table one would require to see the area of those parts?—I can give you an idea, however.

25086. Well, let me put the question in another form. Surely a population of, say 805,000 over that number of square miles is not a very heavy population, is it?—No; you will observe, however, from another table that only about 50 per cent. of the whole area is sewered.

25087. Yes, I see; but dividing your area by your population, what would be the population per acre or per square mile, or any way you like to put it?—That is a question that one could do. Say twenty-three people to the acre.

25088. That would not be a heavy population, would it?—No.

25089. All I want to know is whether you have a very large amount of land not covered by houses?—Oh, necessarily. You will see it from this map; you can see from this at a glance the Borough of Sutton Coldfield has an area almost equal to the area of the City of Birmingham, and in the one case you have a population of 550,000 odd, and in the other case you have a population of less than 20,000.

25090-1. Then a very large part of that would be taken as almost rural land so far as sewage was concerned?—Yes.

25092. As regards Question 24957, do you find that there is practically no further settlement after half an hour; it amounts to that, does it not?—In the one sewage; if you notice the other it is not quite the same.

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25093-4. It is not quite the same ?—(*Mr. O'Shaughnessy.*) In the one case; in the case of the Hockley sewage the suspended matter is of a more granular nature; and consequently, more easily settled; and a sewage containing a very large amount of acids.

25095. Are there houses in the neighbourhood of your works ?—Oh, a great many.

25096. There are no complaints by the inhabitants of those houses of nuisance ?—There used to be, but I am glad to say that recently we have not had any complaints at all.

25097. In 24967 you say, "So far as our observations go, no difficulty has been found in the filtration of chemically treated sewage." Does that imply that there is difficulty in the filtration of sewage which has been treated in the septic tank ?—(*Mr. O'Shaughnessy.*) No, not at all. (*Mr. Watson.*) No, it does not imply that. (*Mr. O'Shaughnessy.*) That was prompted by your question simply; you suggested that there might be a difficulty in the case of chemically treated sewage, and that remark was simply to cover that.

25098. To show that there is no difficulty in that ?—(*Mr. Watson.*) We have found none.

25099. Do I understand in your answer to Lord Iddesleigh on Question 24976 that the cone has its point downwards ?—Yes.

25100. And that the grit settles to the bottom and you can draw it off ?—Yes.

25101. Is it a very shallow cone ?—No, Sir; the tank is 33 feet 6 inches deep or something like that. I will show you a section of it. There it is drawn to a natural scale (*indicating on diagram.*)

25102. Oh, yes. And is it possible for the lighter solids to lie along these slopes ?—That is so; that is one of the reasons perhaps why that is a better septic tank than an ordinary shallow or rectangular shallow tank. (*Mr. O'Shaughnessy.*) Might I indicate what happens in a tank of that description when used as a septic tank (of course, we have experimented on it; we have not deliberately designed tanks of that nature to use them as septic tanks: but we have made observations quite recently), we have had bacteriological examinations made, in connection with the action of such a tank, and we thought in the beginning probably that that tank would abstract organisms as well as sediment; we found to our astonishment that instead of doing so that the organisms were very considerably increased; we would suggest when such a tank as that is being used for a septic tank that the angle of the cone should be a very wide angle relatively.

25103. Are they not very expensive to construct ?—(*Mr. Watson.*) It depends a good deal on the ground you are in; for instance, if a man were to put down a tank like that in a water-logged valley he would probably find it a very expensive tank to construct; but on the site that we have selected for the construction of these tanks we do not even have to shore-up the soil with timber.

25104. They are concrete, I suppose ?—They are made of concrete; at least, the lower part. The cylindrical part is made of brick; the cone is made of concrete; we are fortunate in having placed them in a marl.

25105. Consequently when you have to clean out the tank the stuff would simply be scraped out at the bottom and drained off by a sludge barrel ?—It is hardly necessary; if you notice there is a pipe going right to the bottom. That pipe is for the purpose of conveying the silt away from the tank; by a head of ten feet we are able to drive up that vertical leg of the syphon any silt which has accumulated in the tank, and convey it a distance of three-quarters of a mile, so that by merely turning the sluice valve there we are in the position of being able to clean out your silt.

25106. Then how do you propose to clean the tank if it becomes ultimately necessary when used as a septic tank ?—It is not exactly used as a septic tank; our septic tanks are at Saltley, five miles from the site of those tanks. Those tanks were put in originally with the view of getting rid of the humus which forms the suspended matter in the septic liquor; it is a light material; pretty dense but light, and we find no difficulty and anticipate no difficulty, but from a mere constructional point of view I have taken care that that vertical leg is open at the top, so that I can clean that out at the bottom and if there should be any need to take absolutely everything out of the tank it can be done by pumping.

25107. Yes, I see. In 24983 you speak of the rate of flow and say that a stronger sewage requires "a longer time and certain constituents of sewage being more easily broken down than others." I merely wish to ask if you have data for that statement, or is it on general principles again ?—(*Mr. O'Shaughnessy.*) It is on general principles; paper, etc., is here referred to.

25108. In 29487 you speak of leaving the sludge in the tank just so long as is necessary to deprive it of smell. But does it ever lose smell entirely ?—(*Mr. Watson.*) Entirely; that is one of the best things that we have been able to do, and we have discovered it very largely by accident; but it has completely revolutionised our process of working. Instead now of trying to eliminate organic matter by the gases which are given off in the septic tank, our object is to create sludge of a septic character. That is rather a strong thing to say, but that is what we are doing now, and for the reason that the sludge which we obtain is absolutely inodorous, unless you have got very strong olfactory nerves you cannot smell it at all.

25109. I presume you run this tank as a septic tank first ?—Yes.

25110. For, let us say, some hours ?—Well, not necessarily.

25111. Well, for a long time ?—When we had discovered this first we had kept our tanks running for three and a half years; when the sludge was taken out I was very much astonished to find that it did not smell. The moment I discovered that I had it spread over a whole area, a field of about six acres and I allowed it to lie there. This was done in January; it lay until July; there was never any smell given off, from that field until in July it was so dry that we were able to put the steam plough through it, the land was then turned over, and a crop of rye was sown on it; I did not expect the rye after what my friend Mr. O'Shaughnessy told me, of the amount of metal salts in the sludge, but a fair crop in places has come up.

25112. That is very remarkable ?—It is one of the most remarkable things I have ever known.

25113. I still do not quite follow; do you maintain that the tanks should be run in the ordinary way for a certain time, and then the liquor, I presume, run off finally so as to leave the sludge in the tank ?—Yes. Decanted off.

25114. Then how long do you allow the sludge to lie in the tank before you remove it from the tank ?—Two or three days.

25115. And then the smell disappears ?—Yes.

25116. In regard to Question 24991 I should like to ask if you have actually found that a septic tank can be upset by running storm water through it ?—Yes.

25117. You have spoiled a tank in that way ?—Yes. (*Mr. O'Shaughnessy.*) We spoiled the whole lot of the tanks in that way at one time.

25118. It is the result of actual experiment. Have you details to give as to your answer to Question 24997; you say there was no appreciable difference in the effluent from plain septic tanks and septic tanks filled with rough stones ?—We could give you the figures, Sir.

25119. It would be very valuable if you could, thank you, (*See* Tables at end of evidence, page 648.) In 25004 you give the size of the materials for percolating filters ?—(*Mr. Watson.*) Yes.

25120. And the size you give can be neither called coarse nor fine; it is a sort of half-way size ?—Yes.

25121. I do not think we have data about that size, about the action of that particular kind of filter; what is the object of having it of that particular size; do you find that it does not stop up ?—We find that, yes. (*Mr. O'Shaughnessy.*) In the top layer of the percolating beds, we work them under normally healthy conditions; their normal is anything from a foot up to eighteen inches of nitritial matter which tends to choke the filter, although the amount of activity there must be enormous. We have come to the conclusion from our experience that it would be better to put rather a larger layer on the top and a smaller layer underneath in order if possible to extend that area and thereby prevent choking.

25122. I suppose you have comparative experiments which you could cite in answer to Question 25007 as

regards the single bed versus the two beds ?—Yes. (*Mr. Watson.*) Yes.

25123. These are also got from experimental data ?—Yes. (*Mr. O'Shaughnessy.*) Yes.

25124. And again I should like to ask the same Question as regards 25009. You say, "the best results are obtained from a continuous feed, that is, continous during the period the bed is working, but the filter requires periodical rests." That is also the result of careful experimental investigation ?—Oh, yes, over a considerable period.

25125. In your answer to question 25019, you describe the matter in the suspended solids ; I do not think anyone else has ever taken the trouble to investigate what the nature of that organic matter is ; have you done it microscopically ? You speak of the organic matter present in some of the suspended solids ?—Issuing from the effluent in the percolation filter.

25126. And you examined it microscopically ?—Oh, many times. Provided the bed is in working order, the results are very constant. I might mention here in connection with the mucilage—I might make a further statement in regard to it—it is a question, of course, in which I have taken very considerable interest, and I have a good deal of information on the point ; perhaps I could embody it in the statement in answer to that question.

25127. It would be advisable ; I do not think anyone has troubled about the nature of the organisms in the material ?—I do not know whether you have seen the paper which Dr. Fowler of Manchester has just published ; he read it before the Manchester Section of the Society of Chemical Industry, it was only published in this last journal.

25128. I have not opened my journal yet.—I have the journal here, and I am delighted to find that he has been investigating practically the same question as myself and fortunately for both of us he has covered different ground to me ; he has approached the question from the point of view of the physical chemist, and I have studied it more with regard to its general chemical character, and as far as my biological knowledge goes from a biological point of view. This mucilage that I refer to here he calls colloidal matter, and he studies it both in solution and in suspension, the two things together. I think I would like to make a statement embodying both the matter in his paper and my own experience.

25129. It would be very valuable.—Shall I put it under the head of that question ?

25130. I think it would be advisable ?*—I might state further, Sir, that I notice that a number of experts are considerably confused in their minds with regard to the relations between the suspended matter going on to the bed and the suspended matter coming off. It has been taken too much for granted that the suspended matter in an effluent in a percolation bed has direct relation to the suspended matter in the sewage going on. Provided that you reduce the suspended matter in your sewage going on to the bed down to a reasonable quantity, that is about eight parts per 100,000, which is the lowest figure you can reasonably get out by other than chemical means, if you reduce it to that quantity, then there is no direct connection between the suspended matter as a whole, as far as my experience goes, in the effluent and that in the sewage.

25131. The nature of the suspended matter?—The nature of the suspended matter. I think I state here, do I not, that there is 58 per cent. of organic matter in the suspended solids in the sewage, whereas in the suspended matter in the effluent from the percolation bed it varies between 30 per cent. and 40 per cent.

25132. And consists chiefly of remains of higher organisms ; and then I suppose your organic matter in the effluent consists also of higher organisms ?—Mostly, very low organisms ; bacteria very largely, and vegetable growth, for instance, and some of the higher organisms.

25133. Do you find the aeration test to run parallel to your two permanganate tests ? With regard to Birmingham sewage do they work together. We have had evidence, for example, that at Manchester they do not ; there is a great quantity of reducing salts, and the aeration test—the absorption of oxygen—is not parallel in both cases, so that the albuminoid ammonia test does not run parallel to either of them ?—Well, I have not conducted experiments exactly on those lines—in fact, my experiments have only been too few, because, of course, for lack of time—but I had occasion some time ago to examine a particularly bad sewage (from a manufacturing point of view) which contained quite abnormal quantities of sulphocyanide, and these sulphocyanides, of course, were only partially eliminated by process of treatment, and passed right through even triple contact and triple percolation ; but in testing that effluent by the aeration test I found that the deoxygenation was very high in the case of the effluent containing much of this sulphocyanide ; I compared it purposely with a rather bad effluent from land.

25134. But I am speaking generally ; in Birmingham you do not notice any great difference ; how do you actually take your test ; do you always apply the permanganate absorbed test ?—You mean generally.

25135. Generally, yes ?—I usually conduct the ordinary half-dozen items or so which are usual to be done in the sewage analysis as a matter of routine ; but when there is time for nothing else I do the oxygen absorbed by preference usually.

25136. But not as a regular thing ?—Oh, regularly ; that is almost always done.

25137. It is simply mixing the effluent with aerated water and finding out how much oxygen is absorbed ?—In this case I am referring to permanganate.

25138. Permanganate, yes, I see ?—In the case of the deoxygenation test I usually mix it with one or two dilutions of tap water, shaking it up, and allowing it to stand for half an hour or so before making the first estimation.

25139. Do you regard your effluent as quite satisfactory when it contains sewage fungus ?—What question is that ?

25140. It is your answer to question 25042, paragraph (*c*) You say that sewage fungus grows most luxuriantly in your effluent ; I want to know whether you think it quite satisfactory when sewage fungus grows ?—Well, it is very curious ; I dare say you will think my explanation of that is rather curious ; you will notice that I mention purposely that they grow very luxuriantly, that is this particular class of organisms, in our land effluent ; but I have been puzzled myself for some considerable time as to why such organisms do not grow in the river into which the effluent was passed. There is the observed fact that they do grow in the effluent and they do not grow in the river ; and it needs explanation. Well, my explanation is this, that this particular class of organisms is a very special class, and it grows under very special conditions. As far as descriptions go, as far as my observations go, which coincide with those descriptions, the organisms are almost invariably associated with the presence of iron in the effluent. The presence of iron in the effluent indicates a rather faulty aeration in the filter from which such effluent has come. When the effluent passes into the river it is there under conditions of very excellent aeration ; the conditions are inimical to the growth of this particular class of organisms ; consequently, such growth does not take place. We have further had that exemplified in rather a striking fashion in one of our great main effluent channels. We had these particular growths when nothing but land effluent was passing down that channel growing there so frequently that we had quite regularly to clean it out. Recently, during the last few months we have been passing an increasing quantity of bacteria bed effluent into it. The bacteria bed effluent, of course, is a well aerated effluent, highly nitrified, and does not sustain the life of such organisms as leptothrin and brenothrin, etc. ; the effect is that the land effluent combined with the bacteria bed effluent has produced such a set of conditions that the growth no longer takes place to anything like the same extent ; the men in charge of the channel have noted with astonishment that the growth has disappeared within the last two months.

25141. Very largely owing to the removal of iron ?—Very largely owing to the presence of excess of air.

* NOTE.—The statement referred to was embodied in a paper by Mr. F. R. O'Shaughnessy and Mr. H. W. Kinnersley, read before the Society of Chemical Industry on April 26th, 1906. (See Journal of the Society of Chemical Industry, August 15th, 1906, No. 15, Vol. XXV.)

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25142. That is very curious ?—That is very curious.

25143. (*Colonel Harding.*) The land effluent you refer to as giving rise to this growth of fungus, is it more or less aerated than that from the percolating filters ?—I have not exactly tested the quantity of dissolved oxygen in the percolation bed effluent.

25144. Do you know how much dissolved oxygen your land effluent contains ?—I give it here ; the land effluents contain at a temperature of about six degrees Centigrade, 4.c.c. to 6·2.c.c. per litre dissolved oxygen.

25145. That is very good ?—That is very good indeed.

25146. And what do you get in the percolating filter effluent ?—Well, I have not measured the dissolved oxygen in that.

25147. It would be fully that ; probably more ?—I may point out that in these land effluents, if you take the effluent direct just as it comes down the drain, the aeration is not so good as when it has come a little way down the effluent channel ; these figures which are given here are taken at a point which is before discharge into the stream.

25148. I gather there is no great difference in the amount of dissolved oxygen in the land effluent and that in the effluent from the bacteria beds ?—Not an enormous difference, but the rate of absorption in the land effluent I would anticipate would be considerably higher.

25149. What do you quite mean by that ?—I mean to say, if you incubate the two effluents, the land effluent and the bacteria bed effluent in the absence of air, the rate of disappearance of the oxygen in the land effluent would probably be much greater than the rate of disappearance in the bacteria bed effluent.

25150. Then judging these two effluents by the dissolved oxygen test the land effluent would not be so good ?—The land effluent would not be so good on these conditions—this land effluent, you must remember, is from land which has been treated with a very high quantity of water. Of course, if you have, say, a subsoil, sand and gravel, and you are treating a reasonably small quantity of water on that plot of land, then the reservations I make with regard to our general land effluent would not hold.

25151. Now, this is the point I wanted to make, both in regard to that land effluent and to the effluents on the percolating filters you are surprised to find a growth of the sewage fungus type at all in your channels ?—Yes.

25152. You would have expected that such growth should not be present ?—Well, I should hardly put it in that way.

25153. But you suggest as accounting for it the presence of those iron deposits ?—The presence of iron in the land effluent.

25154. Now, has it occurred to you that possibly light has considerable influence ?—Light ?

25155. And that these fungoid growths which you allude to arise in the dark channels bringing your land effluent to the main channel ?—Well, in the big effluent channel I referred to a moment ago it is fully exposed to the light.

25156. But do you find the growth coming in your channel ?—In the channel.

25157. Or the detritus of the growth in the channel ?—It grows in the channel.

25158. And that is fully exposed to the light ?—Well, it may become all coated over with a deposit and grow over, but as to that I cannot say ; I am not prepared to say how far the influence of light has a bearing on the question. (*Mr. Watson.*) It certainly is exposed to light; there will not be more than nine inches of water in the channel.

25159. And you find the growth to arise there ; you do not find merely the detritus of the growth in the channel ? (*Mr. O'Shaughnessy.*) Well, the growth arises in the first place in the main drain, and it tends always to adhere over any surface over which it is going ; of course, it might accumulate in the first case on the floor of the channel and subsequently grow up afterwards ; but it certainly does grow on the bed of the channel, on the brickwork of the channel.

25160. It is a point which is worth investigation, because speaking generally one has not, so far, found such fungus in well aerated, and entirely well purified effluents ?—It has disappeared within the last two months owing to the introduction of a large quantity of bacteria bed effluent into the channel. All other conditions are the same.

25161. Now, that bacteria bed effluent had not passed, to any extent through underground channels ?—Oh, yes, of course, it had.

25162. But not far ?—(*Mr. Watson.*) About a quarter of a mile.

25163. It is a point which appears to be worth further investigation ?—(*Mr. O'Shaughnessy.*) Yes.

25164. (*Sir William Ramsay.*) I merely want to ask one more question with regard to that : Is it ferrous or ferric iron ?—In solution I think it is ferrous iron, I have not specially studied that point. I might mention I experimented first by mixing water with urine and some ferrous sulphate, and inoculated it with some of the land effluent which had this growth apparently growing in it ; I was not able to induce that growth ; I examined the deposit which occurred ; a copious red deposit occurred in a few days which is usually the case, but on examining that deposit there was no appearance of any growth.

25165. (*Major-General Carey.*) In Question 24195 you state that the central districts of Birmingham where a combined system was in force, a system of storm intercepting drains has been constructed in order to relieve the foul water sewers of surplus flow in time of storm, at what period of a storm do the relief sewers come into operation ?—(*Mr. Watson.*) That depends very much on the extent of the rainfall, and the amount of the rainfall.

25166. I should rather say, at what period are they designed to come into operation ?—From six to eight times the dry weather flow practically. The ordinary storm water sewer which has a fixed sill is very liable to abuse. I have known of a case, I have known of more than one case where 200 per cent. of excess flowed down the ordinary sewer when there was no more than 9 inches of sewage going over the storm overflow sill. In other words the head which is induced by such a large body of water passing over your sill is sufficient to increase the amount of sewage flowing down that sewer, until you have 200 per cent. more than the regulation quantity of six dilutions.

25167. The storm sewage which passes down the relief sewers, of course, is not treated ; it goes straight to the river ?—That is so.

25168. And a considerable volume, occasionally, of very foul sewage passes down the sewers ?—Oh, no doubt ; you mean down the storm water sewers.

25169. Down the relief sewers ?—I think there can be no doubt about that generally speaking.

25170. These relief sewers again would reduce the volume going to the works, would they not ?—Certainly ; yes, that is so. That is absolutely essential I consider ; if you were to take all the sewage down a sewer to the outfall works I am afraid the cost would be prohibitive in the case of a very large district.

25171. Do you mean that you could not possibly take six times the dry weather flow down to the works ?—No. Six times the dry weather flow could be taken down but six times does not anything like represent the storm flow.

25172. Would the sewer not be capable of taking it or how otherwise, why not ?—To construct a sewer which would be capable of taking it would be a very costly matter ; I have known, for instance, of a sewer bringing down 150 times the dry weather flow at one time: 150 times the dry weather flow ; well, it is obvious that if you were to construct an outfall sewer to carry such a large body of water to the outfall works that the cost would be prohibitive.

25173. That of course, but the point was, the outfall sewer has capacity of equal to six times the dry weather flow ?—More ; up to ten.

25174. (*Colonel Harding.*) Did Mr. Watson say there that his sewer was capable of bringing 150 times the dry weather flow ?—Yes ; I will show you the photograph of it; and while I do that I wish to point out that we have quite recently in the city of Birmingham, under the city engineer, constructed a storm water

overflow, which seems to me to meet the great objection which hitherto we have had to all storm water overflows. The great difficulty hitherto has been that as your water rises over the sill which allows the storm water to pass to a river that you increase the head, and, consequently, the volume and velocity of the sewage as it passes down the stream. Now, I will let you see, those who are specially interested, some photographs which I have here showing how that can be obviated. (*Photographs exhibited and explained.*)

25175. (*Major General Carey.*) Is the whole of the dry weather flow of sewage treated on septic tanks and percolating filters before going on to the land ?—In septic tanks always.

25176. And percolating filters ?—No.

25177. What proportion of the sewage is treated on the percolating filters ?—At the present time we are only treating something like 3,000,000 gallons.

25178. 3,000,000 gallons. Is it experimental then ?—Well, I do not call them experimental because we are building new ones as fast as we can build them ; in six months from now I expect we will be treating 8,000,000 gallons.

25179. Is it your intention to go on constructing percolating filters until you are able to take the whole of your dry weather flow ?—Practically.

25180. Then may I ask why are those percolating filters necessary in addition to your septic tank treatment before the irrigation on the land ?—I have tried to explain that we use the land as a percolating filter, but we have already bought between six and seven miles of the valley ; the rate of increase in our district is so great that if we were to go on we should require to buy an acre and a third every week. Well, it simply becomes an impossibility.

25181. Then these percolating filters will relieve the land to the extent that you will be able to provide for an increase of population ?—That is so, and more than that, really. I want to get rid of all our downward intermittent filtration beds ; they are unsightly, they are odorous, they are insanitary, and I want to get rid of every one of them ; I do not mind using the land for broad irrigation.

25182. Then how is the storm sewage treated at present? —We have got storm water filters.

25183. A certain amount of storm sewage goes through the tanks ?—Yes, we take two dilutions.

25184. And after that ?—On to the storm water filters.

25185. It goes on to the storm water filters, and I think you say that the treatment is unsatisfactory ?—Which, General ?

25186. By the storm water filters ?—Oh yes, that is so.

25187. You say in answer to Question 24945, "Storm water filters are inefficient, their primary cost is high, and the cost of maintenance is considerable" ?—Yes.

25188. "Settlement alone in carefully designed tanks would generally be sufficient for the whole flow of sewage and storm water coming to our works after the first flush of the storm (say after two hours)" ?—Yes.

25189. "In the case of a storm of some hours' duration" ?—We have found that these storm water filters—as in the case of storm water filters—that the interstices of the coke choke up very rapidly with putrescible matter.

25190. After sedimentation ?—After sedimentation.

25191. Then do you think that the storm water would be better purified, if it did not go through the filters at all ?—Through the septic tanks ?

25192. No, through the filters ; you have passed it through the tanks, you say, after sedimentation ?—No, I do not put it like that ; we find there is a certain amount of benefit obtained from the storm water filters, but what I wish to point out is that they are most difficult to clean, and the storm very often comes before we have already cleaned them ; when the storm comes, while we are under that condition very little purification takes place, and I feel sure that if we had large tanks to allow storm water to be impounded and the suspended matter to settle down that we could clean them very much more readily and allow supernatant water to flow into the river.

25193. The volume that would be treated in the storm water filters would be over three times the dry weather flow, would it not ?—Probably, over twice the dry weather flow I would rather have it.

25194. Your records appear to have extended over a short period of four months in an exceptionally dry winter ; is such a record sufficient to support the contention that over three times the dry weather flow, and up to six times, may only reach the works in several months, and then only in a very diluted condition ?—I think not. Our statement here is a record of actual measurement.

25195. Extending over ?—Four months ; only in January did we put in our self recording gauges, but our experience, of course, of the works, extends for a very much longer time.

25196. Yes, but without any actual gaugings ?—This has been calculated *pro rata* on the rainfall ; of course, we have taken into account that these four months have been exceptionally dry ; as matter of fact we have only had 50 per cent. of the rainfall during those four months that we have in a normal season.

25197. But you have no actual records to show that your statement as to excess of sewage over three times and up to six times the dry weather flow will only reach the works once in several months ?—I am referring to the four months which have passed.

25198. Again, in 24945 : "The intermittent recurrence of rain does not warrant the provision of expensive works to treat a volume which may only reach the works once in several months, and then only when every stream is in flood" ?—Well, this, you see, refers to actual experience and to actual recorded facts.

25199. That is the point I want to come to ; are your recorded facts based on the four months gauging ?—They are.

25200. And would you consider that sufficient ?—I do not quite go the length of saying that ; I know as a matter of fact that during ordinary winters we have a very much larger quantity of water to deal with than that.

25201. Just so ; therefore, it would hardly be fair to take four months' gauging and say on that, "We will make certain provision for dealing with the additional flow of sewage" ?—I should not like to go as far as that.

25202. Would you not prefer having a more extended series of gaugings, extending over, say, a year or two years ?—I hope to be able to give you in a year's time, if you ask for it, the records for the whole year.

25203. Yes. Coming again to this question : "A maximum rate equal to four dilutions of the normal dry weather flow on the present basis ought to be ample to meet all ordinary contingencies before passing into the water course." That is your opinion more than fact. It is an opinion of your own ?—That is so.

25204. It is not an opinion based on data extending over a long period ?—Based on knowledge. (*Mr. O'Shaughnessy.*) I think partly what led us to that conclusion, sir, was the question of the actual records of Manchester, for instance.

25205. Now you are going to another place. Then I understand you do not propose to pass your storm sewage through septic tanks or a very small proportion ; assuming that the storm sewage over three times the dry weather flow has to be settled in some way before discharge into the river, would you provide separate tank accommodation for that storm sewage ?—(*Mr. Watson.*) Yes.

25206. Have you made any estimate of the cost of such additional provision ?—Well, roughly speaking, yes.

25207. And can you give it to us ?—We could store something like 10,000,000 gallons for £50,000.

25208. That 10,000,000 gallons representing ?—That 10,000,000 would represent——

25209. Three times the dry weather flow and up to six times ?—I should not like to go so far as provide for six times the dry weather flow.

25210. How many dilutions would 10,000,000 gallons represent ?—Two dilutions for about four hours.

25211. (*Colonel Harding.*) Of what ?—Of the dry weather flow.

25212. What is the dry weather flow ?—About 22,000,000 gallons.

25213. Did you not speak of 10,000,000 gallons ?—Yes.

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25214. In what sense is that twice?—That refers to volume and not to rate. I assume that the answer I gave to 24945 is still under discussion, and that for times the dry weather flow and not six times is a desirable unit for a district having an area of 92 square miles. In my view the greater the area of a drainage district, the relative number of dilutions to be dealt with at the Outfall Works should diminish. For instance, in the case of a market town with 10,000 inhabitants, it might very well be necessary to insist on six times the dry weather flow of sewage being treated because the area of the district sewered is likely to be under similar meteorological conditions at one time; but in a large district it is not so. In our district, for example, where the population is from 80 to 90 times greater than the market town to which I have referred, you might have a thunder storm in one part of the district, with a result that from ten to twenty times the normal flow from a small area, inhabited by say 10,000 people, entered the main sewers, without more than appreciably raising the aggregate quantity of sewage flowing to the Outfall Works.

25215. You mean that a storage of 10,000,000 gallons might take in a flow at the six dilutions rate for a short time?—A tank to impound 10,000,000 gallons would store a large proportion of the flow for a short time.

25216. That is the meaning of it?—That is the meaning of it, and if you have the means of taking out your suspended matter quickly, you should draw the water off and allow it to go down with a falling river; then the tanks would be ready to receive the supplementary storm. As at present we cannot clean our storm water filters in unsuitable weather, and this may continue for months on end, and if a supplementary storm comes it finds the interstices of the medium so filled up with putrid matter that the water cannot pass through.

25217. If General Carey will excuse me for one moment, I should just like to make that point quite clear, that the average per hour of your dry weather flow is a little under 1,000,000 gallons?—It depends on the time of the day but the average is just about 1,000,000 gallons an hour.

25218. A little under 1,000,000 gallons, so that if for one hour you had six volumes coming down that would mean 6,000,000; and, therefore, that could be stored in your 10,000,000 gallon tank?—Yes. The land, &c., would probably take twice the dry weather flow, or 2,000,000 gallons, and the remainder would be contained in a 10,000,000 gallon tank until the supernatant water could be let down the river and the sludge pumped out and the tank made ready for a succeeding storm.

25219. (*Major-General Carey.*) Again on question 24945 a much stronger sewage would have to be treated at one period of the day more than another, but does not this apply to all systems of sewage treatment?—I am afraid it does, General; I do not see any way of getting out of that difficulty.

25220. (*Colonel Harding.*) Mr. Watson, General Carey dealt just now with some interesting features of your evidence bearing upon storm water; you recognise, of course, how important it is that the data upon which the judgment is based should be spread over a considerable period?—Yes.

25221. A point of much interest to this Commission is the practicability of dealing with storm waters as a whole. If you are right in telling us that at times an enormous number of dilutions come down into your sewers for a short time, you would, I suppose, conclude that it is quite impracticable for any authority to deal with the whole of its storm waters?—I should think that in the case of a small authority it would be absolutely impossible; in the case of an authority like ours, which extends over a very large area, it is much more possible; because as a rule you do not have a very great storm, such as I have instanced, over the whole district at one time. Thunder storms as a rule are local.

25222. Well, do you think that in framing the resolutions in regard to the storm waters to be treated it is practicable either for a large or for a small authority to deal with the whole of the storm waters so as to prevent the pollution of a stream?—I do not.

25223. You think probably that what will have to guide the Commission and any permanent authority which has to deal with these matters is how much treatment of stormwater is financially practicable?—That is my view, sir.

25224. A point of considerable interest to us would be this: there is at the present moment a provisional regulation of the Local Government Board that six volumes shall be dealt with, some of them fully and some of them partially. Now, when those volumes have been dealt with, how much storm water will still go to the streams. That I am quite conscious is a difficult question for you to answer?—I am afraid it is impossible, sir.

25225. But are you able to suggest to us what dealing with six volumes really means; suppose, for instance, that the total dry weather flow for a year was represented by the figure 100; would the dealing with six volumes represent dealing for the whole year with, say, 50 per cent more, 150?—I should think about 130 altogether, 30 per cent. more than the dry weather flow.

25226. That if the dry weather flow is represented by 100 then the dry weather flow plus the ocasional dealing with six dilutions would mean over the whole year 130?—Yes, but that, of course, would be impossible. During a great flood I have seen the whole of our tanks, the whole of the valley of the Tame impassable; you could not even get a horse and cart across the valley.

25227. Yes, but let us understand what you really suggest to us as being impossible; do you mean that it is impossible at times to deal with six volumes?—No, sir; when I gave you the figure of 30 per cent. above the dry weather flow as representing the aggregate amount of water which comes to a work in the course of a year I wish you to understand that that 30 per cent. does not come to us in gradual regular quantities.

25228. Oh, that one understands, of course; because you yourself told us that at times a very large number of dilutions comes down?—Yes.

25229. And if you are not to deal with more than six you overflow all that comes beyond six; you only get that six occasionally, and at other times you get the volume which is represented by less than six; but what I was anxious to get at was this, that you are quite sure, are you not, that it is not practicable for an authority to deal with the whole of the storm waters?—I am absolutely certain of it.

25230. Then we shall have to be guided by what is financially practicable. You have expressed rather a strong opinion about the provisional regulations of the Local Government Board and objected to them on the ground that they are what you call cast iron regulations which do not take into consideration local conditions and circumstances?—Yes.

25231. But looking at this matter from the administrative point of view it is a little difficult, is it not, to take into account these local circumstances; you must have some sort of general rule, which will no doubt be open to the objection of being cast iron and fixed?—Well, your rule, in my view, ought to be as elastic as possible and it should not be framed until the whole of the local conditions are taken into account.

25232. Is the rule to be framed in that way specially for every authority?—I am afraid that is necessary.

25233. But you yourself, Mr. Watson, ventured to make a suggestion in connection with the treatment of storm waters that in your opinion four volumes of the average would be a practical quantity to be dealt with and form a suitable regulation?—Yes; I wish you to observe that in all the answers which you have here I have dealt with Birmingham, and Birmingham only.

25234. Oh, I quite appreciate that, Mr. Watson?—And when I speak of four dilutions or four times the dry weather flow——

25235. And in recommending four dilutions you are recommending that that would be a suitable regulation to apply to Birmingham?—That is so.

25236. But you will appreciate that probably this Commission will have to make a recommendation in regard to this matter?—Yes.

25237. And we have reached this point, have we not, that we cannot insist on all storm waters being dealt with because that is impracticable?—That is so.

25238. And what one would like to know is what your opinion would be as to a suitable and practicable regulation to make in regard to the number of volumes to be treated ?—The Tame by which Birmingham is built is about 180 miles in length from Wallsall right down to the sea. I think it would be a mistake to ask Hull to do what you would ask Wallsall to do; it is necessary that Wallsall should do a very great deal more towards purifying the head of the stream than would be necessary when that stream assumes the proportions of a mighty river; I can see quite well that it would be a hardship in many ways to insist on a town like Wallsall doing a great deal and letting off a town like Hull.

25239. Excuse me interrupting you a moment; it would seem certainly practicable to draw a broad distinction as between tidal waters like those you refer to at Hull and inland waters like those at Wallsall ?—Well, take Nottingham or Lincoln which are still on the same stream. The Royal Commission have suggested the formation of rivers boards; if formed these rivers boards ought to have the power of rating, and what is being done by a town on the upper reaches for the general benefit of the whole should be spread over the whole district.

25240. That is a suggestion I think somewhat new to us; you think Hull should pay, especially if it is let off in doing so much itself for what is done in the upper reaches of the Aire and the Calder ?—Distinctly.

25241. And the Ouse ?—Distinctly.

25242. That would be rather a difficult thing to carry out, would it not ?—You levy income-tax over the whole country for specific national purposes.

25243. Would this be a transference of local responsibilities to the nation that you would suggest ?—Rather to the watershed, transfer the responsibility to each watershed.

25244. Would it not be more practicable to lay down a certain rule in regard to the number of volumes to be dealt with giving power to a central rivers authority to relax those rules in cases where it might appear to be necessary ?—You might injure Birmingham by allowing Wallsall to do too little.

25245. Then do you give it as your opinion that it is not practicable to lay down any rule in regard to the number of dilutions, that no rule should be laid down, but that it should be left in each case to some central authority to see how many dilutions should be dealt with by this or that authority ?—That is my view, Sir.

25246. Would that not lead to very much bickering and jealousy as between authorities ?—If a rivers board were appointed it would have the whole control.

25247. Well, that is your view on the general question, but in regard to Birmingham you think four volumes is as much as you ought to be asked to deal with ?—That is so.

25248. Not necessarily to deal with the whole four volumes thoroughly ?—Say two thoroughly and two partially.

25249. And you would base that upon the average dry weather flow ?—Yes.

25250. Of course, the proportion at times of maximum flow would be very different to the proportion at times of minimum flow ?—I have pointed that out.

25251. Yes, you have; if the normal flow were taken as one, the maximum flow would be one and half, and the minimum flow about half of one ?—Yes.

25252. So that four volumes of one would only be little more than two of the maximum flow ?—Yes.

25253. The present six volumes which are required to be dealt with based upon the average would represent only about four volumes on the maximum and as much as twelve volumes on the minimum ?—That is it.

25254. An objection has been made that at one time you would be treating a great deal too much and at other times you would not be treating enough, but that is inevitable, is it not ?—I am afraid that it is.

25255. That you must base a rule on average, and it must act unequally at times ?—I do not see how you can get over the difficulty; I have pointed out that volume and not rate is what we should observe; not rate of flow but volume.

25256. This Commission has recommended the formation of a central rivers authority, but until such authority is formed it will be necessary no doubt to lay down some sort of regulation ?—I hope that your recommendation will become law before very long.

25257. It would be very satisfactory if it did, but as yet it has not been carried into effect; and you think the method I suggested of having a fixed number of volumes to be dealt with, with power to relax that on appeal say to the Local Government Board provisionally would not meet the case ?—It might get over the difficulty.

25258. But it is quite clear, is it not, that whether four volumes or six volumes are dealt with, a large quantity of storm waters will at times pass to the streams ?—There is no doubt about it at all.

25259. I see the total rainfall in your district is represented by 32,500 million gallons ?—Yes.

25260. And how much of that, do you suppose, would reach the sewers—50 per cent ?—Roughly, perhaps, about 50 per cent.

25261. That would mean 16,250 million gallons; and your dry weather flow is 8,000 million gallons; so that if you dealt with 30 per cent. more than the 8,000 there is a large balance to go to the stream ?—Yes.

25262. You have no doubt about that, that beyond four or six volumes there must be a large residuum going to the stream ?—I have no doubt about it at all.

25263. As to the method of treatment of storm waters, some increase may be made in the flow through the regular plant ?—Yes.

25264. But not a great increase ?—Not for any length of time.

25265. Because if that septic tank flow is regulated upon your average daily flow at times it has already increased to one and a half times, has it not ?—I have known it to be as much as four.

25266. That is rather exceptional ?—That is exceptional.

25267. But daily it rises to 50 per cent. more than the average daily, quite apart from rain ?—You may say 50 per cent.

25268. Does it rise to double ?—Yes.

25269. Therefore, automatically, every day, quite apart from storm waters, your plant has to pass a larger flow at one time than another ?—Yes.

25270. And if the tank area is based upon the average, there is very little room for really increasing the number of volumes dealt with if you reckon them upon the twenty-four hours ?—That is so.

25271. But as far as practicable, especially at times of average and of minimum flow, it will be possible to deal with a certain number of dilutions through the existing plant ?—Yes.

25272. Through the dry weather plant ?—Yes.

25273. And when you get beyond that you think it will be better to deal with the storm waters first of all by sedimentation ?—That is my view.

25274. In many cases you think that that sedimentation alone would be sufficient ?—I think so.

25275. The alternative system of passing crude storm waters over storm beds is inadvisable because the bed acts largely as a mechanical strainer, and what you strain off is very difficult to remove ?—That is it.

25276. And if it be desired after sedimentation of storm waters to carry the purification further you probably would prefer to have some percolating filters in reserve used occasionally and kept in condition, but used in reserve rather than to increase the flow very much through the normal tanks ?—I would rather increase the working power and capacity of the ordinary plant than provide storm water filters to deal with storm water *per se*.

25277. Then the effect of that course would be, that at times of dry weather the filters would be working very easily ?—Easily; they might be rested.

25278. Therefore very efficiently ?—Efficiently, and it would be for the benefit of the filters.

25279. Probably you considered it of greater importance in regard to the purification of rivers that the dry weather flow should be efficiently treated, rather

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than that an attempt should be made to deal with all these storm waters less efficiently?—I hold that view most strongly.

25280. There is a peculiarity in your septic tanks at Birmingham, to pass on to another subject, that you deposit comparatively little in them. One knows of course, of instances where the sewage passes direct to the septic tank, and where all the heavier matters are deposited in the septic tank, but in your case you have extensive detritus tanks first?—I have changed that.

25281. But you have them still?—I have them still; but since you saw them——

25282. I know that your detritus tanks are depositing less now than they deposited at first; you are throwing more into the septic tank?—I am putting a wall across the end of the tank nearest to the inflow pipes, for the purpose of constructing detritus tanks and small sedimentation tanks; the whole of the rest of the million gallon tanks are being used as septic tanks.

25283. Yes, you are giving the septic tanks more to do?—Much more.

25284. I find in your answer to Question 24986 you tell us that in 1901 and 1902 the difference between what passed to the septic tanks and what passed away from the septic tank was only four parts per 100,000?—Yes.

25285. And I find in the same answer you tell us that in a later period the quantity passing through the roughing tank and through the septic tank differed, but after all about the same quantity was left in the septic tank again, about four parts, and that is very little?—Very.

25286. In your latest data, with your present system of working, I find you are leaving thirteen parts per 100,000 in the septic tank?—Yes.

25287. That is to say, as the effluent issues from the roughing tank you have thirty-two parts, and as the effluent issues from the septic tank you have nineteen parts?—(*Mr. O'Shaughnessy.*) That is referring to the table.

25288. Yes, in 24956 the table that you give, the effluent from the roughing tanks contained thirty-two parts of the effluent; from the septic tanks nineteen parts?—(*Mr. Watson*) Yes.

25289. So that now thirteen parts are left in the septic tank?—Yes, but even since that time ——

25290. You have increased it further, have you?—I have increased it very much more.

25291. I see?—I have been pumping out the sludge from the sedimentation tanks into the septic tanks; in other words, I have been promoting septic action for the purpose of obtaining deodorised sludge.

25292. Are you able to give us the quantity of suspended matter that is left in the septic tanks now including this addition from the settlement tanks?—I am afraid I cannot.

25293. But it would be in excess?—(*Mr. O'Shaughnessy.*) That figure 32·2 is virtually bigger on account of the sludge which is pumped, as Mr. Watson has just said, from the sedimentation tanks into the septic tanks. That would virtually raise the figure 32·2 to a somewhat higher quantity; we can give you the figure later on.

25294. But we may take it generally that more matter than the thirteen parts is now being left in the septic tank?—(*Mr. Watson.*) Yes.

25295. The reason I wanted to bring that out somewhat more clearly is this, that one has heard it quoted in connection with Birmingham that septic tanks could work for a number of years without accumulations arising, and I think I am right, am I not, in coming to the conclusion that that condition of things was only possible when you left only four parts in the septic tanks?—Yes.

25296. Therefore there was nothing remarkable in the tanks working long periods without accumulations?—That is so.

25297. Any deductions from that example to show that there has been almost complete consumption of suspended matter in septic tanks would be wholly wrong?—Altogether wrong; as matter of fact, we have never been able to show that more than 10 per cent. has been eliminated by the action of the septic tanks, notwithstanding the fact that some other places——

25298. As much as 30 per cent.?—As much as 30 per cent.

25299. For instance, I think at Manchester and Leeds and Sheffield?—Yes, and Exeter.

25300. But I think, Mr. Watson, that that does not include the digestion which you suggest yourself takes place in your long conduit and in your Dortmund tanks?—That is quite right.

25301. There would probably be some digestion in both those features of your work?—No doubt about it at all, rather than extend the septic tanks we have utilised the great conduit for the purpose of still further creating fermentation.

25302. You probably do not think the estimate which has been made at these other places and which is based upon all the matter left in the septic tanks, the bulk of which being so left, is far wrong, 30 per cent.?—It may not be.

25303. You are unable yourself to verify it, but you are not surprised at that figure?—I am not surprised.

25304. But you would be greatly surprised if anybody suggested to you that the great bulk of the suspended matter coming down in sewage is digestible?—I should be very much surprised to hear that.

25305. There is another feature of your evidence which is interesting to us, because it is to some extent different to what we have had from other places, and that is that your experience of septic sludge and septic tank liquor is that very little, if any, nuisance arises in dealing with either?—There is no doubt about the fact.

25306. That you would rather have to deal with septic sludge than settled sludge or than chemically precipitated sludge?—Very much, rather.

25307. Should I be right in taking it that the reason of this absence of nuisance is due to the fact that in the case of natural settlement, of chemical precipitation, the putrefaction of the sludge has not begun, and therefore, if the sludge is placed upon the land, that the whole of it has to take place; whereas in the case of septic sludge you are withdrawing suspended matter which has to a large extent passed through these putrefactive stages?—I think that is right.

25308. So that any nuisance that may exist with septic sludge will last for a shorter period than would the nuisance arising from other sludge?—Yes, and that septic sludge ought not to be withdrawn until the putrefaction has been complete.

25309. Then that leads me to ask you this question, how far is it practicable to maintain something like a constant capacity in a septic tank by the frequent withdrawal of small portions of the sludge from the septic tank?—That is exactly what I am trying at present; I cannot answer the question from knowledge; but I think we will probably find that it will be practicable to withdraw sludge from the septic tanks once every three or four months.

25310. Or even more frequently?—Well, I tried the other day to take it out after two months, but I found that while it was quite practicable that it was spending money unnecessarily; there was not sufficient in the tank to warrant it being taken out.

25311. If it is not necessary to remove it, you don't remove it?—Exactly.

25312. But when it becomes necessary to remove it you would prefer a partial removal at frequent intervals rather than waiting until there is a great accumulation at the end of some years?—I regard that as being essential. When I first emptied the septic tanks about eighteen months ago, after an accumulation of three and a half years, I emptied the tanks wholly. I had difficulty in promoting the fermentation in the tanks again; it took me some months to do it; but when I emptied the tanks this year I only partially removed the septic sludge; I left about nine inches on the bottom of the tank to inoculate the sewage with the putrefactive organism immediately.

25313. Evidently that is necessary?—It is.

25314. The complete emptying and sweeping clean of a septic tank is a mistake?—It is; it is quite a mistake

25315. And therefore if it be practicable to remove septic tank sludge from time to time so as to maintain a constant capacity you would think that that was a thing most desirable to be done ?—Yes.

25316. A very important matter in connection with the septic tank is, of course, the point to which you can reduce the suspended matter in the effluent ?—Yes. It is obviously desirable, as far as possible, to leave suspended matter in the tank ?—And it is cheaper and better in every way.

25317. It is better because there is some consumption, and cheaper because you can deal with it there in a wholesale way ?—Yes.

25318. And it facilitates your filtration ?—It does.

25319. In your case you are carrying away from the septic tanks a considerable quantity of suspended matter, and I understand the object of your Dortmund tanks is to further reduce that ?—To take out the humus which is left in the septic tank liquor.

25320. To take out as much as possible of the remaining suspended matter, whatever it may be ?—Yes.

25321. And you think it practicable by the use of such tanks following upon the ordinary septic tanks to reduce the suspended matter in the effluent to about eight parts ?—By 75 per cent.

25322. That is somewhat further than the eight parts, if you have at the present moment about twenty parts coming away from your septic tanks you are able by the Dortmund tank to reduce them to five ?—Yes, but it is not so much when it gets down to the Dortmund tank. And then, as Mr. O'Shaughnessy reminds me, we have got sewage from a population of 60,000 or 70,000 coming in between Saltley and Minworth, the site of the Dortmund tanks.

25323. Which does not pass through the first septic tank ?—Which does not pass through the first septic tank.

25324. Then are you able to tell us, Mr. Watson or Mr. O'Shaughnessy, how much suspended matter comes to the Dortmund tank ?—(*Mr. O'Shaughnessy.*) About thirty two.

25325. So much as that ?—So it makes 75 per cent.

25326. And that reduced 75 per cent. gives you your eight parts ?—Yes.

25327. Now a filtration of effluent containing 8 parts is quite practicable on the beds of the size of material that you use ?—(*Mr. Watson.*) It is.

25328. And you use these beds as percolating filters ?—Yes.

25329. Is the material of one size throughout, or is it graded ?—It has been graded. I have adopted different sizes of material, but I have come to the conclusion that the best sizes for our purpose are the sizes given in the third paragraph of 25004.

25330. Those are the sizes that you are adopting ?—Yes.

25331. And the lower material is coarse ?—The lower material is coarse.

25332. And what is the top surface grade ?—Three-quarter inches to one and a quarter inches.

25333. Now, of your 8 parts going upon such a filter, does much remain on the top mechanically strained off by the material ?—We get in the effluent about 8 parts, well, from 6 to 8 parts per 100,000.

25334. In the effluent coming on to the filter ?—No, the filtrate coming off the filter.

25335. Well, of those 6 to 8 parts does much remain on the surface of the filter kept back by the material ?—Yes, a proportion is retained and oxydised on the surface.

25336. Then it is a little difficult, is it not, to remove that from a filter with material so coarse as one inch ?—We have not found it necessary to remove it at all.

25337. Do you think that it will accumulate on the surface or does it pass through the filter ?—It passes through the filter; the safeguard of a percolating filter is that you are enabled to allow particles in suspension to pass right to the bottom.

25338. That is the point I was coming to; in your case, the safeguard is not fine material on the surface, and mechanical straining of the suspended matter brought to the filter, but the material so coarse throughout that such matter can find its way through the filter and come out in the effluent ?—Yes, if it were possible otherwise to reduce the amount of the albuminoid ammonia in the filtrate I would much prefer to have less of this fine material and more of the coarse right through, but we have found that with very coarse beds the amount of albuminoid ammonia has not been reduced as far as we think it should be; we have had a corresponding increase in the nitrates, but Mr. O'Shaughnessy advises me that that is not nearly such a good effluent as an effluent with a low albuminoid ammonia, although it has correspondingly less nitrates.

25339. But that, interesting as it is, is a little off the point which I was going to, that it is not practicable to put upon a filter absolutely clarified effluent; you must have some suspended matter ?—Yes.

25340. In your case you consider it practicable to reduce that to 8 parts ?—That is so.

25341. Now, of that 8 parts the whole will by no means be digestible; some parts of that must necessarily ultimately remain somewhere ?—I think so.

25342. Either in your filter or afterwards in your effluent ?—Yes.

25343. And you consider it an advantage that percolating filters should be made sufficiently coarse to allow the undigestible matter to come through ?—Yes, that is my view.

25344. Provided that not more than 8 parts go to the filter, do you think it would be necessary to have any subsequent process after such percolating filtration ?—Yes, I think it is necessary.

25345. Even with so little as 8 parts ?—I think so, and I have just quite recently, in fact within the last few days, found out how that can be done very inexpensively.

25346. No doubt that will be interesting to us; will you tell us ?—What I am doing at the present moment is to pass the filtrate into something in the nature of a Dortmund tank, I propose to call it the Birmingham Separator, which has the result of eliminating the suspended matter to the extent—we have brought it down to 1·6 parts per 100,000, and that at a cost of something like 1s. 6d. per million gallons.

25347. That is very interesting. Now, of the eight parts going on to such a filter how much comes out on an average with the filtrate before it goes into such Dortmund tank ?—Oh, about six.

25348. But that would be a very variable quantity, would it not; I mean that it varies between wide limits ?—It does.

25349. Sometimes you get more coming out than goes on ?—Yes, we have found that.

25350. And at other times quite a small quantity coming out ?—Quite a small quantity.

25351. But if you take it on the average of a larger number of tests you think it would be in the proportion of about six to eight ?—Six to eight.

25352. And for the purposes of settlement you do not think there is anything better than something like a Dortmund tank?—I am now quite sure of it; I have tried, as I have indicated here, a number of methods.

25353. And that system of tank is incidently of great advantage in permitting the deposited matter to be removed without interrupting the work of the tank ?—That is so.

25354. Now, suppose instead of putting eight parts per 100,000 on to the filter it were possible to put only four parts, in that case probably you would get so little suspended matter in the effluent as not to make it necessary to have a subsequent process, would you not ?—Well, that might, but we have not found it possible to put on less than eight parts.

25355. We had some interesting evidence yesterday to the effect that it was possible in the Staffordshire district to carry out septic sedimentation in a way to only leave four parts per 100,000 in the septic effluent; have you any idea how that can be attained; you cannot do it at Birmingham, can you ?—No, we have not been able to do it.

25356. But, of course, the question arises whether it would be better to spend money in more complete

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settlement even if need be by the addition of chemicals rather than to spend it after the percolating filtration in a subsequent process ?—Well, if you can do it for 1s. 6d. per 1,000,000 gallons, I am quite certain no chemical can approach that in cost.

25357. The whole question is one of finance ?—Yes.

25358. It is perfectly possible to reduce the suspended matter by chemical precipitation to four parts and even less ?—I believe that is so.

25359. And to reduce it to such a point that you would not require a subsequent process after the percolating filtration ?—Well, Mr. O'Shaughnessy has rather found out as you inferred from an answer to Sir William Ramsay a rather interesting thing; he points out that the nature of the suspended matter coming off the filter is so very different from any of the suspended matter going on to it.

25360. Yes, I think his suggestion was that besides the suspended matter going on to the filter, besides the indigestible portions of the eight parts there was added matter which had arisen in the process of filtration, which had not come to the filter at all ?—Quite.

25361. Animal matter which either was then living or which had been living, in the body of the filter ?—Yes, well, that being the case, you see it is something in the nature of an excreta from the bed, assuming that to be a living organism.

25362. That leads you to think, does it, that however perfect your sedimentation might be before the effluent reaches the filter that it is quite conceivable that there would be suspended matter coming out in the filtrate although exceedingly little had gone on to the filter with the effluent ?—I have come to that view.

25363. That therefore it will be necessary in any case to have a subsequent process ?—That is so.

25364. And therefore if you have to have a subsequent process you need not spend so much money in reducing the suspended matter in the effluents ?—Yes.

25365. Is that clearly your view ?—That is quite clearly my view. We have observed more suspended matter coming from a secondary percolating bed than from the primary bed.

25366. That raises rather an interesting question; beyond a certain point you may actually do harm by continuing filtration ?—I think you get a better effluent, taking it as a whole; but you still have—the point which I make is: you still have that suspended matter to deal with.

25367. But I think Mr. O'Shaughnessy's point is this, is it not, that if you pass even a fairly well purified effluent through a further process of fitration you may create suspended matter ?—Yes, I think that is his view.

25368. And bring about an evil which was previously non-existent ?—Yes.

25369. Is not that it ?—(*Mr. O'Shaughnessy.*) That is quite so, Colonel Harding.

25370. That is evidently a point to be carefully kept in view in connection with sewage disposal works. I remember seeing myself an instance of that kind of an effluent which appeared to be thoroughly clarified, and which passed upon a percolating filter and brought about a filtrate which had very visible suspended matter ?—(*Mr. Watson.*) Yes.

25371. Which, as far as one was able to judge, was the detritus of a growth occurring in the filter itself ?—Yes.

25372. Then briefly, in regard to the comparison of various methods of settlement, septic, chemical, natural, one must take into account the local circumstances, the character of the sewage, the local levels and many other points, before one can say definitely which is the best to select ?—Certainly.

25373. There is no such thing as saying, in the disposal of sewage, this or that plan is the right plan to follow ?—No, I do not think that one can possibly lay down the law and say that because one method is successful here that it must be equally successful there.

25374. It may in some cases be desirable to chemically settle sewage, and, as far as possible, clarify the effluent which is to be filtered; in other cases, you need not be at all particular; you may allow a good deal of suspended matter to go on to the filters and deal with it in the second process of filtration ?—That might be so.

25375. There is just one point which I should like to ask your opinion about, whether you have ever considered the possibility of dealing septically, not with sewage, but with sewage sludges ?—We have; I tried that about two years ago; I had sludge pumped into one of our septic tanks; I filled half of the tank; I afterwards introduced septic sewage into it for the purpose of inoculating it, and, much to my surprise, thsre was no visible result for six months, and even after that time I think we allowed the sludge to remain in for something like——

25376. There was no flow through it at all ?—There was a very very quiet flow through it.

25377. A flow of what ?—Of sewage.

25378. Do you think it brought about toxic conditions which prevented the development of septic action ?—I do not think so. If I had begun quietly, if I had brought in a small quantity of sludge and laid it on the floor of the septic tank, and introduced sewage in a highly septic condition thereafter, working upwards instead of working downwards as I tried to do, I might have had good results; but I introduced too much sludge to start with, and the organisms were evidently on the surface and did not work downwards quickly enough.

25379. Well, it occurs to me to ask you this, because in some cases,—though apparently not at Birmingham—nuisance seems to have arisen from the spraying of septic tank effluent, we have been told that in certain cases there is considerable development of sulphuretted hydrogen, and that complaints have been made of the spraying of septic effluent ?—So far the spraying of septic sewage has given rise to no complaint.

25380. And it would seem as if there was an advantage in dealing with sewage as far as possible when it is fresh ?—We have not found that.

25381. To adopt a fairly rapid method of sewage disposal; I am quite aware that at Birmingham this difficulty has not arisen ?—It has not.

25382. It might be worth while for me to ask you if you think the presence of considerable salts of iron in the sewage tends to counteract the creation of nuisance ?—Well, it might, but we have found from a small installation which I recently put up for one of the Birmingham institutions that the septic sludge had precisely the same inodorous properties, and that was from an entirely domestic source, the sludge which we have got on the works——

25383. Well, I gather, as in your case no nuisance arises from dealing either with septic sludge or septic effluents, you have not considered it necessary to make investigations in that direction ?—That has been my experience.

25384. In 25005, in the last paragraph, you say something about the exceptional difficulties of secondary filtration; I suppose you mean percolating filtration ?—Is that the paragraph beginning "A good effluent . . ." ?

25385. No, the last paragraph, "In the case of a secondary filter, which deals with liquid partly purified, the elimination of the remaining impurities is much more difficult than the first reduction" ?—Yes.

25386. Well, would you mind explaining to us why that should be so ?—(*Mr. O'Shaughnessy.*) That, by the way, was a provisional answer which was really put in by a clerical error; there is a table here in the answer to Question 25005; that is the one you are referring to, I think.

25387. Yes ?—The answer really finishes with that table: "Tank Liquor." "Bed A." "Bed E." and below that.

25388. Where does the passage I referred to belong to ?—It belongs to 25007.

25389. But still, whether it belongs to 25005 or 25007 the statement is one which you make and to which you adhere, Mr. O'Shaughnessy ?—I am not quite clear, Sir; is this under 25005, the last paragraph of all: "In the case of a secondary filter, which deals with liquid partially purified, the elimination of the remaining impurities is much more difficult than the first reduction, and it would seem that the depths of a second filter should be greater than the primary bed" ? We adhere to that statement certainly, Sir.

25390. Then how do you account for this increasing difficulty of final purification ?—Because it is purely on physical action owing to relative dilutions; I mean the more pure a liquor gets the more difficult it is to eliminate

the residual impurity, for the simple reason that the concentration of the solution gets so very low. It is purely a physical question.

25391. You think it would be largely a waste of money if a certain process leads to a purification which may be considered fairly satisfactory; to bring that to a much higher degree of perfection by repeating several times the process of purification?—Certainly.

25392. The little good you would effect on your dilute impurities would not by any means be worth the cost?—That is quite so, Sir.

25393. And I suppose that we may gather from that generally that your opinion is that it is more easy to deal with a strong than with a weak sewage?—Yes, that is so. (*Mr. Watson.*) It is more easy to get a certain percentage of purification from a strong sewage than from a weak sewage relatively.

25394. It is more easy to bring purification up to a given point also?—(*Mr. O'Shaughnessy.*) Yes, Sir, that is so. To put it quite clearly, Sir, given a certain quantity of organic impurity to eliminate, and suppose that quantity of organic matter were distributed over 1,000,000 gallons as compared with 500,000 gallons, then it would be much more easy to eliminate the impurity from the 500,000 gallons than from the 1,000,000 gallons.

25395. (*Mr. Stafford.*) In reply to Colonel Harding, Mr. Watson, I think you said you proposed to give certain rating powers to rivers boards; the rating board would be over the whole district?—(*Mr. Watson.*) Over the whole.

25396. That would be both urban and rural districts as they exist at present?—It would, on the principle that riparian owners along the stream benefit from the amount of purification which is obtained higher up the stream.

25397. Therefore, you would have in cases like Birmingham the rural district outside paying for the purification of Birmingham sewage?—Well, suppose that you did.

25398. Would you suggest that they should pay in the same proportion?—Well, that is an administrative question which perhaps would require consideration; I refer to the general principle as being right.

25399. And you would have also Wallsall and all the other towns you mentioned paying for the purification of Birmingham sewage; you would have every town, in fact, included in the rivers board area paying for the purification of the sewage of Birmingham?—Well, you could not ask Birmingham to do more than what is physically possible.

25400. No?—Consequently if you wish something to be done which is outside what any body of sensible men would propose it would be only right I think that the whole area should pay for that. Personally I do not think the treatment of 6 times the dry weather flow from an area of nearly 100 sq. miles is reasonable, and if it is demanded, the cost of treatment should be spread over the whole watershed.

25401. Yes, but I do not know that you could ask them to pay in the same proportion for the treatment of the sewage of a big town like Birmingham, which gets very distinct advantages from its size and from its trade? And to make a rural district pay in the same proportion would hardly commend itself to the rural districts?—Well, that is a point for consideration, and it would be of value to take the experience of the Purification Board on the water of Leith water shed into account. In that case a private Act was granted by Parliament, and rating powers were given to the Board by which one rate was levied on one class of polutors and another rate on owners of land who were not guilty of any pollution.

25402. To pass from that, how long have your Dortmund tanks been in operation?—Nearly two years now.

25403. And you have found them satisfactory?—Very satisfactory, without exception, satisfactory.

25404. You are an advocate for the treatment of tank effluent by continuous filters as opposed to contact beds?—Yes.

25405. Why?—Because I found when we employed contact beds that they choked up very readily, the water capacity in those contact beds very readily went down, and I was afraid as an engineer to recommend my Board to go into the question of putting down a great area of beds the medium of which I knew would require to be renewed from time to time. It landed me in this difficulty, that I wanted a loan for works for, say, thirty years. I would have been bound to have admitted that part of my work would be no use in the course of five or six years. I did not want to get into that position.

25406. Well, is that applicable only to your own sewage, to Birmingham sewage?—I have dealt with Birmingham here and Birmingham alone.

25407. Would not the same sort of thing apply elsewhere?—To a very large extent. I can conceive of conditions where levels are so very unfavourable that it might pay one to put down contact beds, but unless the levels were very unfavourable to percolating filters, I should recommend the putting down of percolating filters without hesitation.

25408. What would be the comparative cost between the two?—I think that the percolating filter works out rather cheaper.

25409. Not in construction, does it?—Per 1,000,000 gallons treated, taken in conjunction with the strength of the sewage.

25410. Yes?—And that is the right way to look at it.

25411. It does work out cheaper?—Yes, I think there can be no doubt about it at all.

25412. And therefore, the life of the percolating filter is longer?—The life of the percolating filter, constructed of granite or similar material, so far as one can see, is indefinite.

25413. (*Sir William Ramsay.*) Do you wash out the percolating filters from time to time?—The bottom?

25414. No, wash them out, wash them through?—We have not found that necessary, but you can do it; you see the material is of larger size. But only ten days ago, a fortnight ago perhaps, we had a bed opened which had been at work for nearly two years; we found that the bed was in a cleaner state at the end of two years working than it was when we constructed it.

25415. (*Mr. Stafford.*) Have you had large experience with the contact bed?—No. That is the reason why we have not thought it advisable to answer your contact bed questions; I am quite sure there are others who can give you much more reliable information with regard to contact beds than I can.

25416. But you are still strongly of opinion that your own system is the cheaper system?—Oh, there is no doubt about it: the physical conditions of the site chosen for the works contribute to this, of course.

25417. And the more efficient?—And I think the more efficient. I need not point out to the Commission that in the figures which I have given the cost of strong material is referred to; I have given no costs of such material as clinker and engine ashes, and material of that kind which is liable to resolve in water, or to break down by the action of air and water; I have given granite, gravel, broken Staffordshire brick, and slag material which will not resolve in water.

25418. In connection with that, what are the chief characteristics in your opinion of a good material for percolating filters?—I think almost any material can be used. The view which I have is that the interstices form a habitat for the organism; and that if you use a material which will not break down, you have there a filter which is absolutely indestructible.

25419. So that hardness is the first qualification?—Yes.

25420. Would limestone be as good as granite?—I do not think so; it might for some time be even better, but where you have lime you have liability to disintegration.

25421. So that on the whole you think granite is the best material you can use?—I think on the whole that the order in which we have placed these is right: granite comes first.

25422. Granite, broken bricks, cinerated slag?—Yes, then comes gravel, then furnace clinker. I may say, as regards gravel, that our experience has been that the particles are too smooth, that on occasions when you have to run a larger quantity of sewage over your bed there is a liability to wash the organism out of the bed of a smooth surface: still, it is a good material, and in some cases cheap.

BIRMINGHAM, THAME AND REA DISTRICT DRAINAGE BOARD.

Record of Analyses of Effluents from Closed Septic Tank Filled with Stones.

Date of analysis of Sample.	Nature of Sample.	Results expressed in parts per 100,000.							Colour.	Smell.	Appearance.	General Remarks.
		Estimated on dissolved and suspended matters.			Chlorine.	Nitrates and Nitrites as Nitrogen.	Dissolved Solid Matter.	Suspended Matter.				
		Oxygen absorbed in 4 hours.	Free and Saline Ammonia.	Albuminoid Ammonia.								
	Septic Effluent -	9·49	5·56	·89	24·9	Nil.	118·0	11·0	Yellowish	Very foul	Very turbid	Taken 11.0 a.m.-5.0 p.m., 19.6.00.
	„ „ -	9·44	5·14	1·05	26·1	„	130·0	5·0	„	„	„	„ 7.0 „ 5.0 „ 27.6.00.
	„ „ -	12·28	4·49	·77	27·6	„	133·2	7·3	„	„	„	„ 9.0 „ 5.0 „ 18.7.00.
	„ „ -	7·25	4·26	·75	27·6	„	122·0	11·0	„	„	„	„ 9.0 „ 5.0 „ 23.7.00.
	„ „ -	13·77	—	—	—	—	—	—	—	—	—	„ 25.7.00.
	„ „ -	6·84	—	—	—	—	—	—	—	—	—	„ 10.0 „ 6.0 „ 30.7.00.
	„ „ -	9·96	—	—	—	—	—	—	—	—	—	„ 9.0 „ 5.0 „ 31.7.00.
	„ „ -	12·68	5·00	·69	23·9	Nil.	146·0	9·5	Yellowish	Very foul	Very turbid	„ 9.0 „ 5.0 „ 1.8.00.
	„ „ -	13·70	—	—	—	—	—	—	—	—	—	„ 6.0 „ 6.0 „ 2.8.00.
		10·60	4·89	·83	26·0	Nil.	123·8	8·8	—	—	—	Average.

Record of Analyses of Effluents from Open Septic Tanks Not Filled with Stones.

Date of analysis of Sample.	Nature of Sample.	Results expressed in parts per 100,000.							Colour.	Smell.	Appearance.	General Remarks.
		Estimated on dissolved and suspended matters.			Chlorine.	Nitrates and Nitrites as Nitrogen.	Dissolved Solid Matter.	Suspended Matter.				
		Oxygen absorbed in 4 hours.	Free and Saline Ammonia.	Albuminoid Ammonia.								
	Septic Effluent -	12·47	4·66	1·01	29·0	trace	130·2	16·3	Yellowish	Very foul	Very turbid	Taken 9.0 a.m. to 5.0 p.m., 18.7.00.
	„ „ -	7·37	—	—	—	—	—	—	„	„	„	„ 9.0 „ 5.0 „ 23.7.00.
	„ „ -	8·94	5·20	·95	25·5	none	123·0	15·0	„	„	„	„ 9.0 „ 5.0 „ 24.7.00.
	„ „	10·94	—	—	—	—	—	—	—	—	—	„ 25.7.00.
	„ „ -	6·35	—	—	—	—	—	—	—	—	—	„ 10.0 „ 6.0 „ 30.7.00.
	„ „	9·65	5·37	·95	27·3	none	124·5	11·4	Yellowish	Very foul	Very turbid	„ 9.0 „ 5.0 „ 31.7.00.
		9·29	5·08	·97	27·3	—	125·9	14·2	—	—	—	Average.

EIGHTIETH DAY.

Thursday, 15th June, 1905.

PRESENT.

The Right Hon. THE EARL of IDDESLEIGH (*Chairman*) presiding.

Major-General CONSTANTINE PHIPPS CAREY, C.B., R.E.
Colonel T. W. HARDING, J.P. D.L.
Mr. W. H. POWER, C.B., F.R.S.
Sir WILLIAM RAMSAY, K.C.B., F.R.S.
Mr. T. J. STAFFORD, F.R.C.S.I.

Mr. F. J. WILLIS (*Secretary*).

ALSO PRESENT.

Dr. A. C. HOUSTON.
Dr. GEORGE McGOWAN.
Mr. G. B. KERSHAW.
Mr. C. C. FRYE.

Mr. GEORGE WATSON, M. Inst. Mech. E., A.M. Inst. C.E., Managing Director of the Horsfall Destructor Co., Ltd., of Leeds and London, called in; and Examined.

Mr. George Watson, M. Inst. Mech. E., A.M. Inst. C.E.

15 June 1905.

25423. (*Chairman.*) You are, I think, Mr. George Watson, managing director of the Horsfall Destructor Company, Ltd.?—That is so, my Lord.

25424. I think you are of opinion that it is practicable to get rid of sewage sludge by burning it in destructors?—Yes, my Lord, it is.

25425. Can you burn the sludge alone, or has it to be burned in combination with town refuse?—I should say that it never could be burned alone; I think you should always have something to absorb the moisture, and I think town refuse is generally found the most convenient material.

25426. In what proportion must the house refuse be to the sludge?—I should say that that depends entirely on circumstances; it depends on the sludge and it depends on the refuse, but generally I should think one of sludge to two of refuse by weight.

25427. Now, can you tell me this: in a town of, say, 20,000 inhabitants, would there be sufficient house refuse to enable the whole of the sludge to be burned?—I think so, my Lord.

25428. That the house refuse you may practically say in all cases largely exceeds the sludge in quantity?—I think so. It depends partly, my Lord, on the method of precipitation of the sludge. As regards the sewage in some cases they take more sludge out of it; in some cases less; but I think in every case, whether with a perfect or imperfect precipitation of the sludge, you would have enough refuse to burn it.

25429. Can sludge be burned as it comes out of a settling tank, or does it require to be pressed or treated in any way?—My experience so far has been almost confined to pressed sludge. In one case I burned sludge for a short time which had been standing in the open air and had become air dried to a certain extent. I think if the sludge were allowed to be air dried or settled and to get "spade-able" that you could always burn it without pressing and thereby get a great economy, but it must be inconvenient in many cases to let it stand long enough to get to a "spade-able" condition. If it is too moist to be "spade-able," I think it would be better to be treated either by pressing or by air drying.

25430. Do you know at all what the cost of pressing sludge is; how much per ton?—That is a little out of my department, but I believe it is 2s. per ton of the average of the pressed material.

25431. Are you satisfied that the sludge and the house refuse can always be burned without creating any nuisance?—Perfectly. My firm invariably guarantees that and takes the responsibility of it for a period entirely.

25432. How many towns have you had actual experience in?—Two, my Lord—Bury and Huddersfield; and I might add Chesterfield was the place where this small experiment was tried with the air-dried sludge.

25433. How long have you worked in these two towns?—The tests that were carried out were in each case made shortly after the plant was set to work; in the case of Bury the test was made on March 11th, 1902.

25434. But do I understand that you have been burning the sewage at Bury since 1902?—No, my Lord, but the plant is there ready to burn it at any time. I think the burning lasted about eighteen months. I am not absolutely clear about that as to the exact date when they stopped the regular burning but they worked regularly, I think, for eighteen months.

25435. At Bury?—It would be easy to ascertain exactly by writing; but I do not know for certain the exact length of time.

25436. You said Bury and somewhere else?—At Huddersfield.

25437. What has happened at Huddersfield?—At Huddersfield the test I referred to was made on the 8th December, 1898, and I believe the plant was worked for two years at Huddersfield.

25438. It was stopped there?—They first burned the sludge with refuse, but they found that the cost of carting refuse out from Huddersfield was very high, as the plant was so far from the town, and then they burned the sludge for a time with coke breeze, and I believe they got very good results from that. I understand that for some time past they have not been using the plant; I think they are now finding another method of getting rid of the sludge, which costs them less.

25439. (*Mr. Power.*) Is the destructor at the sewage works?—In both cases; and in both cases it is a long lead from the town, it is about three and a half miles, I think.

25440. (*Chairman.*) Can you tell me what the cost was of establishing your works at Bury and Huddersfield?—I can give it you approximately, although my firm only carried out a portion of the work. The buildings and the chimney were built in each case by the town themselves, but I think approximately at Huddersfield it would be £1,500 in addition to the plant already existing on the works, which comprise a large chimney; and in the case of Bury, I think it would be about £12,000 complete, including the chimney which was built specially with the view to the destructor.

25441. (*Mr. Power.*) The destructor in each instance being intended to deal with sludge as well as the town refuse?—Yes.

25442. (*Chairman.*) £12,000 at Bury?—At Bury, yes.

25443. Then taking Bury; what would you reckon the actual cost of the upkeep of the installation?—May I give it to you in shillings per ton; if I give it to you in that form I think I can give it more nearly than in any other way, because I have not the detailed figures beside me.

25444. Do?—I think it better; it cost 1s. 6d. per ton for every hing except the capital charges; when I say "ton" I mean, of course, the ton of mixed refuse

Mr. George Watson, M. Inst. Mech. E., A.M. Inst. C.E.

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and sludge in the proportion of two of refuse to one of sludge.

25445. At Bury and at Huddersfield, too, was your plant calculated to take the whole of the sludge and the whole of the town refuse?—At Bury it was, but at Huddersfield it was only an experimental plan of two cells which were put in to replace a former plant which had been much more extensive. The former plant had been discontinued, I believe, mainly because it had not a drying hearth; there were certain difficulties experienced, and they decided to pull that plant down and put in two of our back-fed cells, the same as the model I have shown you.

25446. But at Bury it was calculated to destroy the whole of the town refuse and the whole of the sludge from the sewage?—I think not exactly, my Lord; I believe at Bury it was quite big enough to burn the whole sludge of the town, but they were taking some of the refuse in another direction, I think they found there was actually more refuse at Bury than was required to deal with the sludge.

25447. (*Sir William Ramsay.*) There are just one or two questions I should like to ask; I suppose there is no objection to burning more house refuse than the proportion of two to one? You can deal with house refuse pure and simple?—Oh, certainly; it of course gives a better result.

25448. Are you affected by lime present as regards the sort of clinker formed; sometimes you say it is hard, sometimes soft, sometimes more or less porous; does that depend upon the amount of lime present in the sludge?—I do not think lime is particularly injurious except in this way, if you are using a great deal of lime in the sludge and you afterwards wish to make the clinker into concrete works, you must be very careful that that lime does not afterwards burst up the concrete.

25449. That is to say, it remains lime; it does not become carbonate?—If there is a great deal of lime present it would have to be slaked, and if it were slaked afterwards, the clinker and the lime would have to be slaked together for any concrete works in order to slake the lime in the clinker as well as the lime added.

25450. In giving your estimate of cost at 1s. 6d. per ton, I suppose you are making no allowance for the profits on the clinker sold as such, or made into artificial stone, or used in any way?—No, I am making no allowance for that.

25451. Is there any allowance to be made on that at all; is it a profitable article, in other words?—I think that the clinker made from sludge need not be always sold. I think in many cases it could be used for filter beds, but the main revenue that you can get for burning is the steam that it is possible to raise, provided you have a use for that steam on the sewage works; for instance, if you wished to pump.

25452. In making an estimate of 1s. 6d. per ton, are you taking into account the value of the steam raised and deducting it from the amount?—No, I am taking that from the actual cost, but, as I said, I have to qualify that; I am not absolutely certain of the exact figures at Bury; what I have done is to prepare a statement of what can be done now. The Bury work is somewhat old now, and it is impossible to go by it; but I have made a complete statement of what can be done in the matter of sludge burning.

25453. Could you give the cost and say whether there would be any considerable deduction from that 1s. 6d. on account of the saving in the cost of steam raised by ordinary fuel; I mean, in the roughest possible way, would it take 6d. or 1s. off; would it reduce it at all?—I reckon if you can use the whole of the power raised for the whole 24 hours you can realise 8d. a ton of mixed material as against burning coal, and paying for stokers' wages to burn the coal; of course, that depends entirely on the cost of coal in the district and a great many other factors.

25454. Do I understand you rightly to say that the 1s. 6d. could be reduced to 10d.?—Yes.

25455. (*Major-General Carey*). Before providing a destructor of refuse and sludge a local authority would have to very carefully consider whether the cost of cartage of refuse to the destructor or the sludge to the destructor would repay the cost of working the plant?—Precisely, sir, I think that every case has to be considered on its merits very carefully in regard to the local conditions, and I think that if there is a very long lead for the refuse that it would pay to have mechanical transport for the purpose.

25456. And a destructor for dealing with compound refuse and sludge would principally be useful where pumping is required?—Precisely. That is where the great utility of it would come in.

25457. You would not be in favour of providing a destructor for refuse and sludge where there was no pumping?—Yes, sir, if the lead from the town was not too far and if there was a difficulty in getting rid of the sludge by selling it to the farmers or in a more profitable way.

25458. Then in the case where there is a market for pressed sludge would you consider it advisable to destroy the sludge afterwards?—No, sir, if you can get a market for the sludge it will, of course, pay better to sell it.

25459. Only in this case, then, where there is no market whatever for the sludge?—Or where the market is irregular. In some cases the farmers will take it at one time of the year and not at another, and then you will have it accumulating and you would have danger of nuisance from the accumulation. I have not had experience of treating sludge by drying, but I should like to say in cases where you have a destructor at work the heat from the destructor might be used for drying the sludge into a "poudrette" instead of pressing it at all; by having steam-jacketed cylinders and treating the sludge as they do the pail contents at Rochdale, for instance. The "poudrette" is much more valuable as a manure than the pressed sludge.

25460. As I understand, you have not made any experiments for destroying sludge without its being mixed with refuse?—No, sir, except in the case of Huddersfield, where for a time they burned coke breeze with it instead of refuse.

25461. (*Mr. Stafford.*) What is the situation of the destructor at Huddersfield; is it near inhabited houses?—No, it is a good distance from inhabited houses; it is at a place called Deighton.

25462. At Bury are there inhabited houses near?—At Bury there are houses comparatively near it.

25463. Have there been any complaints of nuisance?—None at all; so far as I have heard.

25464. In either of the towns?—No; we burned it without any nuisance to the neighbourhood.

25465. Is there any nuisance that you could recognise yourself, independent of the people in the neighbourhood?—No, none at all.

25466. No smell from the drying sludge?—No; because, you see, it is all passed through the full heat of the main flue; and we maintain a temperature of over 1700° degrees there, a bright-red heat; and it entirely burns up all fumes; there is also a dust catcher which catches the dust. I have brought a model to show you how that is done. I believe in many cases what is thought to be smoke from a destructor shaft is really fine dust. We have a special means of extracting that and so making the products of combustion quite clear.

25467. From your practical experience you say there is no nuisance at all arising from the sludge destructor?—No, we should not be in the least afraid of that.

25468. What kind of clinker do you get?—The clinker at Bury was certainly more porous and more spongy than the clinker we get when we are not burning sludge.

25469. Is there much lime in it?—I think there was a considerable proportion of lime.

25470. It is very soft and friable?—Yes, very soft and friable.

25471. Therefore it would not be very useful for bacteria beds?—No, I believe they found, as a matter of fact, that it was not so good as ordinary clinker for bacteria beds.

25472. (*Colonel Harding.*) Your experience has been limited entirely, has it not, to the burning of sludge in connection with the town refuse?—Yes, sir, that is so, except in the case where they left off burning town refuse and burned coke fuel with it.

25473. Was that fuel purchased for the purpose?—Yes, at Huddersfield.

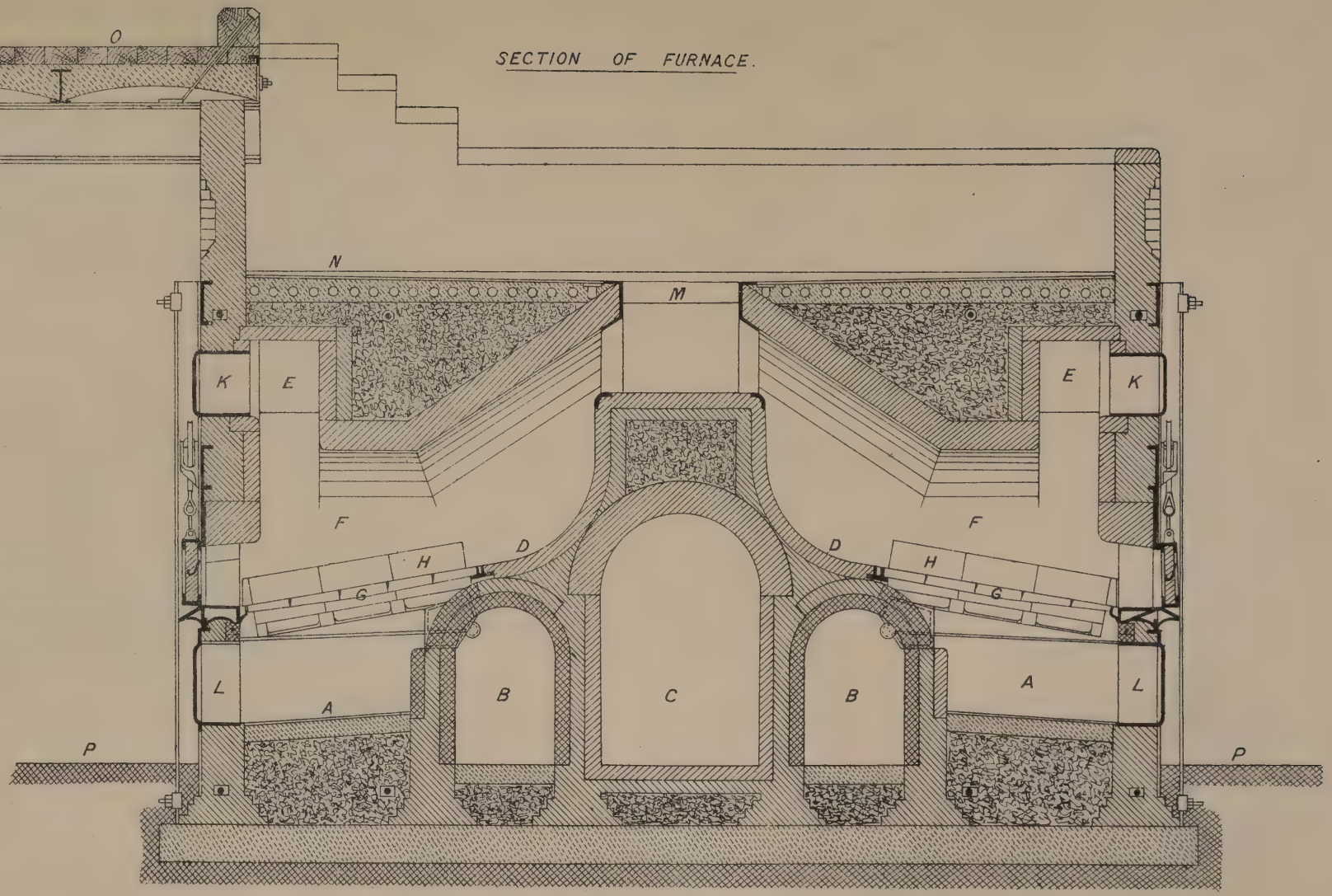
APPENDIX TO MR G. WATSON'S EVIDENCE.

6 CELL "HORSFALL" DESTRUCTOR AT BURY.

Back to Back Type.

A	Ashpits
B	Blast Flues
C	Combustion Chamber
D	Drying Hearths
E	Outlet Flues
F	Furnaces
G	Grate Bars
H	Side Boxes
J	Clinkering Doors
K	Cleaning Doors
L	Ashpit Doors
M	Feedhole
N	Feeding Bin
O	Tipping Platform
P	Clinkering Floors

SECTION OF FURNACE.



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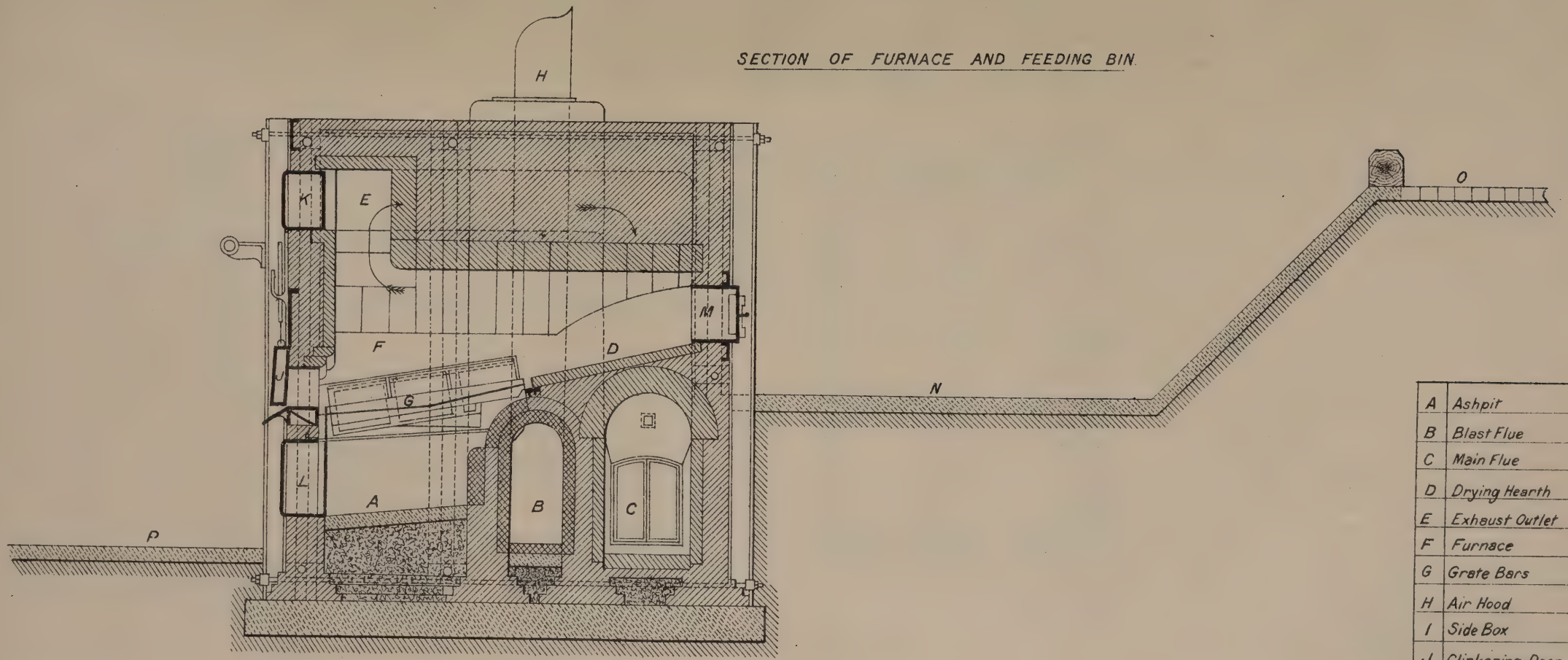
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Appendix to Mr G. Watson's Evidence.

2 Cell Horsfall Destructor at Huddersfield.

Back Fed Type.

Section of Furnace and Feeding Bin.



A	Ashpit
B	Blast Flue
C	Main Flue
D	Drying Hearth
E	Exhaust Outlet
F	Furnace
G	Grate Bars
H	Air Hood
I	Side Box
J	Clinkering Door
K	Cleaning Door
L	Ashpit Door
M	Feeding Door
N	Feeding Bin
O	Tipping Floor
P	Clinkering Floor

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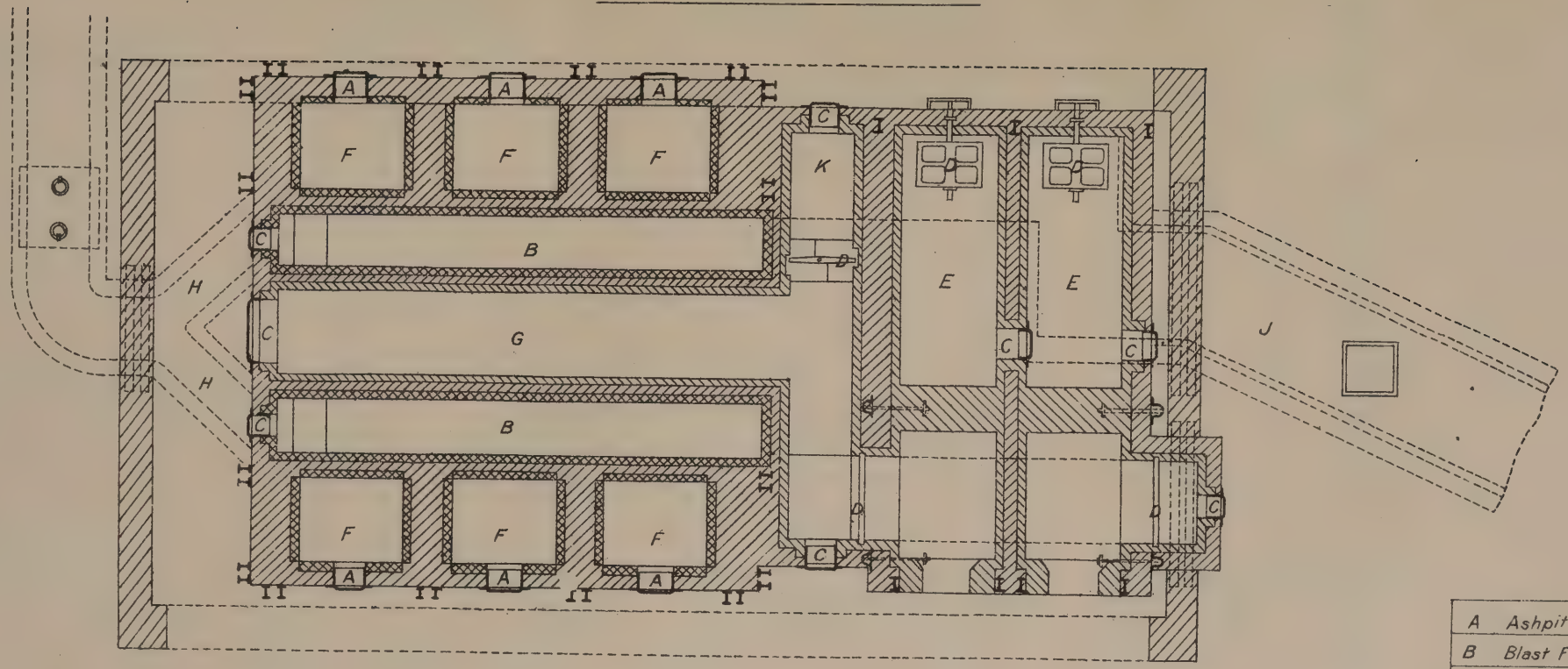
Royal Commission on Sewage Disposal.

APPENDIX TO MR G. WATSON'S EVIDENCE

6 CELL HORSFALL DESTRUCTOR AT BURY.

Back to Back Type.

PLAN OF FURNACES AND BOILERS



A	Ashpit
B	Blast Flues
C	Cleaning Doors
D	Dampers
E	Boilers
F	Furnaces
G	Main Flue
H	Blast Inlet Flues
J	Outlet Flue to Chimney
K	Bye Pass

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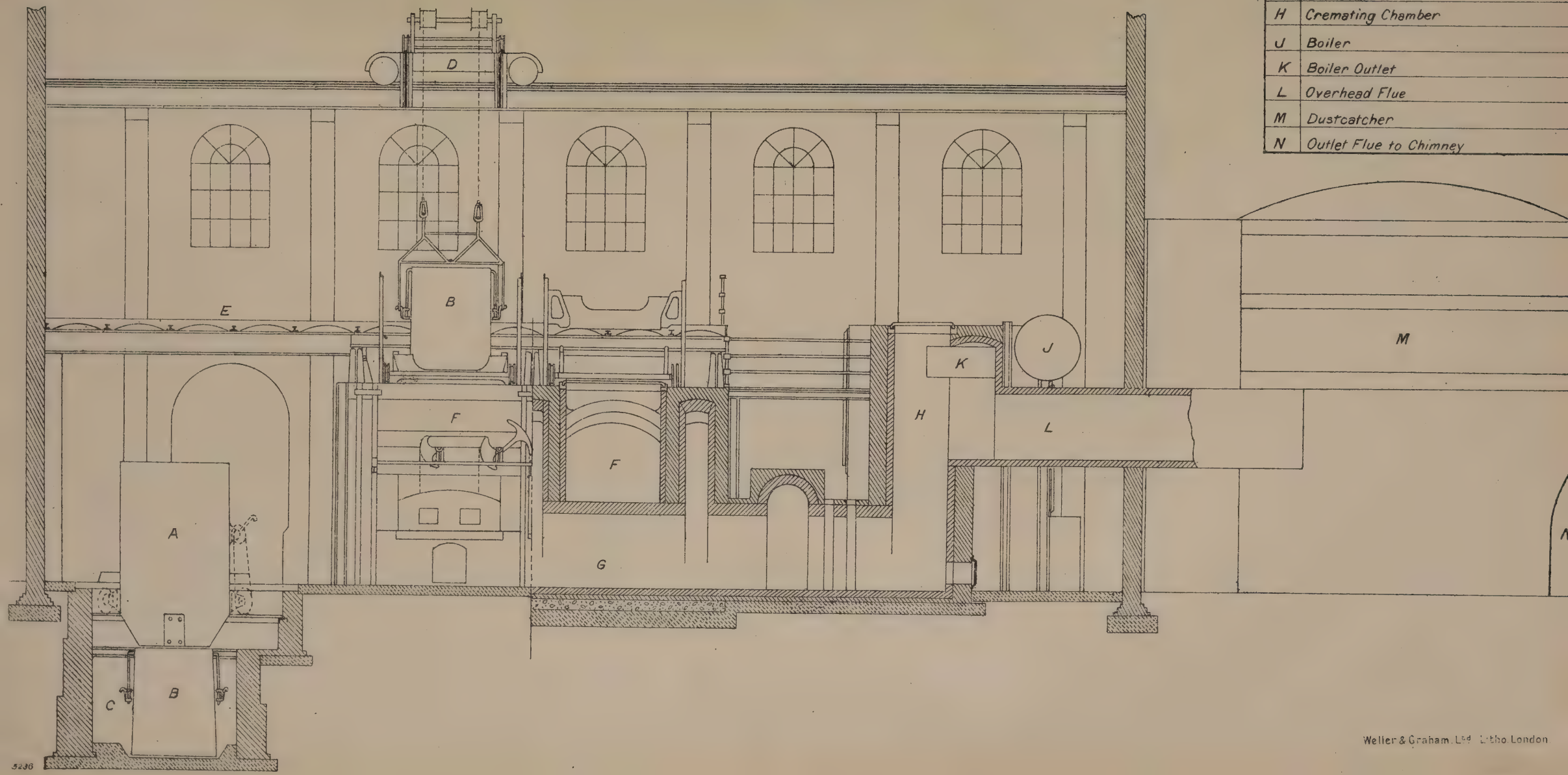
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APPENDIX TO H. S. WATSONS EVIDENCE.

"HORSFALL" CONTAINER FED FURNACE.

SECTIONAL ELEVATION.

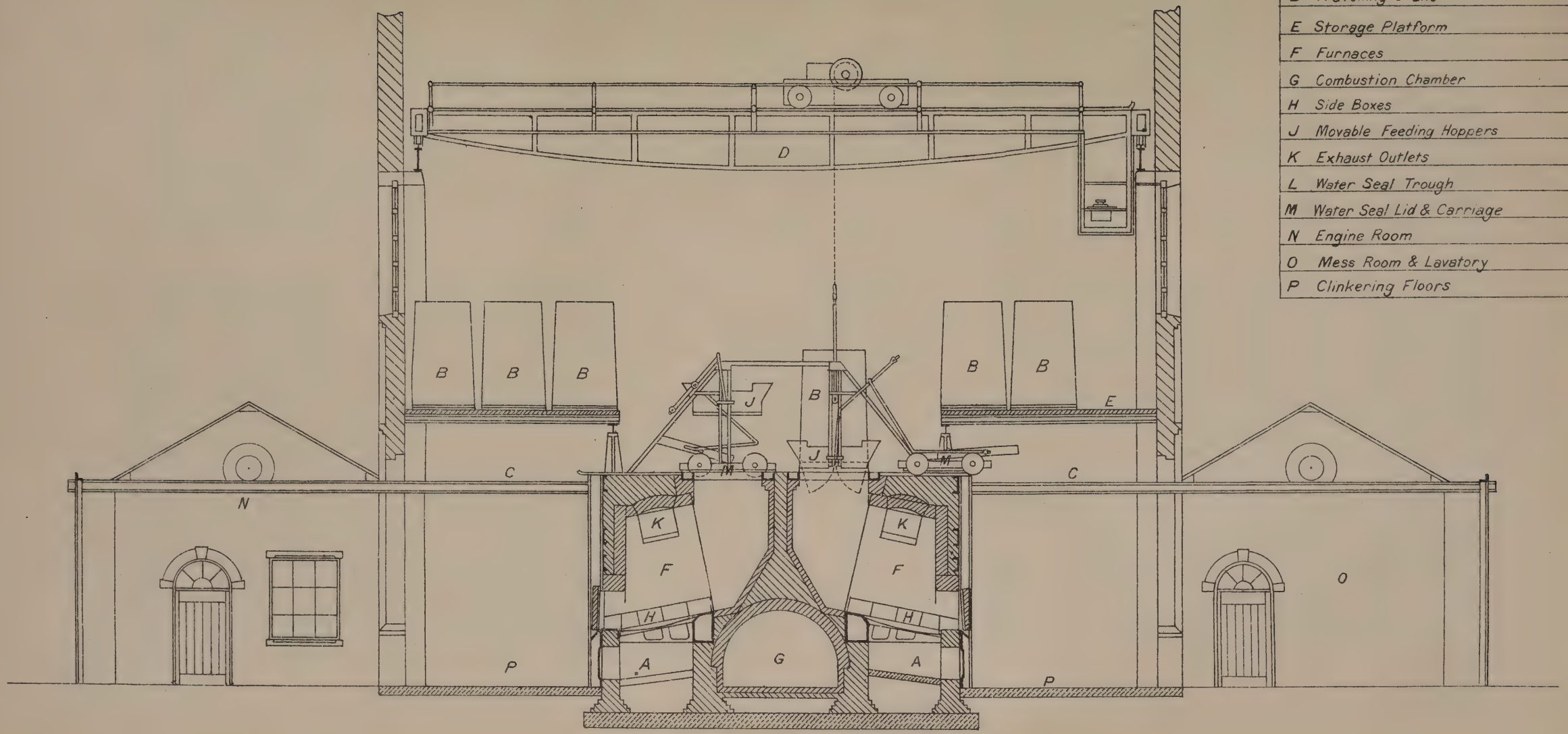
A	Swivelling Hopper
B	Containers
C	Tipping Pit
D	Travelling Crane
E	Storage Platform
F	Furnaces
G	Combustion Chamber
H	Cremating Chamber
J	Boiler
K	Boiler Outlet
L	Overhead Flue
M	Dustcatcher
N	Outlet Flue to Chimney



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"HORSFALL" CONTAINER FED FURNACE

CROSS SECTION



A	Ashpits
B	Containers
C	Overhead Clinker Railway
D	Travelling Crane
E	Storage Platform
F	Furnaces
G	Combustion Chamber
H	Side Boxes
J	Movable Feeding Hoppers
K	Exhaust Outlets
L	Water Seal Trough
M	Water Seal Lid & Carriage
N	Engine Room
O	Mess Room & Lavatory
P	Clinkering Floors

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25474. The position of sewage works necessarily is often outside a town and in a situation unsuitable for a destructor ?—Unsuitable from the point of view of the heavy cartage, yes, sir, that is so.

25475. We should be therefore particularly interested to know your view as to the practicability of dealing with sludge independently of the refuse; is it a matter to which you have devoted any attention ?—No, sir, except that I can say this, it can be done easily with bought fuel.

25476. Do you think it is financially practicable to burn sludge without town refuse, but with the addition of some low class fuel ?—I think there are very few cases where it would be financially practicable.

25477. Where it would be financially practicable ?—Yes, I think in most cases there would be other means for disposing of the sludge, which would cost less money than burning it with bought fuel.

25478. We must not use that term loosely; there is sludge and sludge; when you speak of the destruction of sludge by burning you mean sludge which has been considerably dried ?—Yes, pressed or air dried.

25479. You do not mean liquid sludge. Your view is that there is considerable financial difficulty in dealing with sludge by burning and your reference is to dry sludge; quite obviously it is impracticable to deal with liquid sludge ?—Oh, yes.

25480. The cost of evaporating the water would be all too great ?—It must be either air dried or pressed; lying in outside tanks for a time.

25481. What do you find to be the proportion of water in the pressed cake ?—I believe it varies from 70 up to 90 per cent., according to the amount of pressing.

Mr. George Watson, M.Inst. Mech. E., A.M. Inst. C.E.

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25482. But there is not above 70 in the cake ?—Well, I should say it was a bad result if above 70.

25483. Have you not many cases of less than 70 ?—I cannot say at this moment; I have no doubt it can be done.

25484. I notice in the figures you give us, the figures are 70. Then, in your experience, we are to take it that sludge cake contains 70 per cent. of moisture ?—Yes.

25485. In your experience, when you speak of the practicability of burning cake, you are referring to cake containing 70 per cent. of moisture ?—That is so.

25486. You are not very sanguine of dealing financially with cake by the addition of very low class coal in the neighbourhood of a colliery, are you ?—Well, I think if you could get colliery pit heap you could almost get that for nothing; in a case like that it would pay.

25487. If you can get a colliery heap near a sewage works and mix small coke with the dry cake you could so burn it ?—Yes, in that case it might pay.

25488. One may take it the fuel value of the cake itself is practically nil ?—That is so.

25489. Unless it be in a case like Elland, where there might be grease in the sewage ?—Yes, in ordinary cases it would take all the fuel value to evaporate the water.

Mr. Walter Francis Goodrich, Assoc. Inst. Mech. E., called in; and Examined.

25490. (*Chairman.*) You are, I think, Mr. Walter Francis Goodrich, the London manager for Messrs. Meldrum Bros., Ltd., Timperley, Manchester ?—Yes, sir.

25491. I understand that you are of opinion that it is practicable to get rid of sludge by burning it in a destructor ?—Yes, sir.

25492. Will you tell me whether you think that you can burn sludge alone, or must it be burned in combination with house refuse ?—Well, in reply to that I think I should be inclined to say that it would depend a great deal on the composition of the sludge. I have in mind particularly the case of Elland, where the sludge is of a rich character, and in similar cases I think it would be possible to burn the sludge when it had been pressed, even without mixing it with refuse.

25493. In the ordinary case you consider that at all events it is very desirable that it should be mixed with house refuse ?—That is so.

25494. And in what proportion should the house refuse be to the sludge ?—Two to one is a very good proportion.

25495. Well, then can you say in a town, we will say, of 20,000 inhabitants, would there be house refuse enough to enable the whole of the sludge to be burned ?—I should say so in the average town.

25496. Taking the proportion of 2 to 1 ?—I should say in the average case there would be.

25497. In the average case there would be ?—Yes.

25498. Can sludge be burned as it comes out of a settling tank or must it first be pressed or treated in any way ?—It is certainly advisable to take as much of the moisture out of it as possible either by exposure to the atmosphere, by draining, or by pressing.

25499. What is the cheapest way of treating the sludge ?—Do you mean for extracting the moisture ?

25500. Yes ?—Well, the cheapest way, I should think, would be to expose it to the atmosphere and to drain as much of the moisture off as possible; and in some places we get very good results; in that way reducing the percentage of moisture very considerably, even beyond what has been accomplished with presses in other instances.

25501. Can you give us any estimate of what the cost of air drying the sludge would be per ton ?—That, I am afraid, I could not give you.

25502. Or of pressing the sludge per ton ?—I am afraid I could not give you the cost of pressing the sludge per ton either.

25503. Do you feel sure that in all cases it is possible to burn sludge and the house refuse without creating a a nuisance ?—Oh, yes, undoubtedly.

Mr. Walter Francis Goodrich, Assoc. Inst. Mech. E.

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25504. In what towns have you had actual experience ?—Bolton Corporation, Elland Urban District Council, Leyton Urban District Council and Walthamstow Urban District Council.

25505. That is four ?—Four.

25506. Will you say in each case how long you have worked there ?—Leyton is a matter of ten years, Bolton three years, Elland about two years, and Walthamstow is quite a new plant; it has only been in operation for about three months.

25507. Then we may leave that last out; you have been working at the other three places for years; you are working there still, are you ?—Some years, we are working there still.

25508. Can you tell me in each case what the cost of establishing your works was ?—Well, at Leyton the plant is a pretty big one; it is dealing with, I think, about 140 tons of refuse and sludge per day; there is seventy-five tons of refuse and seventy tons of pressed sludge. The total cost in that case was £9,000, including engines and boilers, the chimney, and a hoist for lifting the sludge on to the top of the cells. Of course, the engines really have nothing whatever to do with the destruction of sludge, but they were merely put in as part of the entire plant at that time.

25509. Then the cost of establishing works is £9,000 ?—£9,000.

25510. And have you any idea of what it costs annually to keep them up ?—Yes, in this case, according to the latest figures available—this is at Leyton—£150 per annum; but again, unfortunately, in that annual amount they have included the cost of upkeep for the pumping plant as well, which, of course, has nothing to do with the refuse or sludge destructor.

25511. Now, do these works deal with the whole of the sewage ?—So far as I am aware, they are burning the whole of the sludge they have available at Leyton in addition to the whole of the refuse collected.

25512. In fact the works at Leyton destroy the whole of the sludge and the whole of the town refuse ?—Exactly.

25513. Very well, that is Leyton; now as to Bolton ?—Bolton is, of course, a more recent example; it has been in operation now for about three years. The destructor was primarily erected, I think, to destroy the

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whole of the sludge with a proportion of house refuse; but unlike Leyton the Bolton works are situated some considerable distance out of the town, two miles south I think, from Bolton, and the authorities have not found it advisable to continue carting refuse such a considerable distance in order to burn it along with the sludge; therefore, at times they have burned a proportion of coal dust with the sludge rather than cart the refuse out. Then, although the destructor was primarily erected for destroying sludge owing to the difficulty of disposing of it by other means, since that time they seem to have been able to get rid of sludge to farmers from time to time, and at the present time I think farmers are occasionally taking it; they have a sludge store there, and sometimes they have some sludge on hand; at times they have plenty of sludge to destroy; at other times they have no sludge to destroy at all; it seems to fluctuate very considerably.

25514. (*Mr. Power.*) It is pressed sludge?—All pressed sludge, sir.

25515. (*Chairman.*) What was the expense of erecting your plant there?—The Bolton plant cost about £7,000.

25516. And what is the annual cost of the up-keep?—The annual cost of the up-keep at Bolton, £14 per annum. Of course, it is hardly fair to compare a case like Bolton, where the destructor has only been in operation three years, with a case like Leyton, where they have been working for 24 hours a day for ten years. Then in the one case the repairs cost is confined to the destructor pure and simple; and in the other case there is pumping plant and so forth included, which has nothing to do with the destructor.

25517. At all events the plant at Bolton is calculated to burn the whole of the sludge?—Oh, yes, it would destroy the whole of the sludge without any difficulty.

25518. Well, then, what was the cost of establishing your works at Elland?—At Elland the cost was within £3,000, but in that case, of course, the plant is very much smaller.

25519. Was it calculated to destroy all the sludge?—Oh, yes.

25520. And all the town refuse?—And all the town refuse.

25521. (*Mr. Power.*) And its relation to the town—is it far away?—Oh, it is quite central, sir; it is combined with the electricity works.

25522. And the sewage disposal works?—And the sewage disposal works.

25523. (*Chairman.*) Does it destroy the whole of the sludge and the whole of the town refuse?—Yes. and unfortunately, owing to the occasional scarcity of refuse and the scarcity of sludge the plant is rather frequently idle; I believe it is idle at the present time.

25524. But it does actually destroy the sludge?— Oh, yes, it is capable of destroying the whole quantity without any difficulty.

25525. Yes, I mean it is not only capable of it, but it does do it?—Oh, yes, it does do it.

25526. And it does do it regularly?—It does do it when the material is available.

25527. And what is the annual cost of the up-keep there?—Up to the present time nothing at all; it has been working 1½ years; nothing whatever has been spent so far.

25528. (*Mr. Power.*) Elland I am speaking of now, being centrally situated, as you say, has there been any complaint of nuisance arising from the process?—Nothing whatever that I am aware of.

25529. Is it near to houses?—Yes, it is near to houses.

25530. What class of houses—artisan?—Mostly artisan, I think, sir; it is a small manufacturing town.

25531. And at none of these places have you had any complaint of nuisance?—Not that I am aware of, sir; of course, in the case of the Bolton——

25532. I mean there has been no formal complaint to the authorities?—No, sir.

25533. When you are driven to burn small coal in the absence of town refuse, do you burn it in the same proportion to the sludge as if you were using town refuse, or is it less?—Oh, considerably less. I should say, to take an average case, 1 cwt. of dust coal to 1 ton of sludge.

25534. In the proportion of 1 to 20?—Yes, sir.

25535. (*Sir William Ramsay.*) I see you state that there is a very considerable calorific value from sludge cake in excess of that required to evaporate the water?—Yes sir.

25536. Could that calorific value be used to dry the sludge rather than make it into sludge cake; I want to put the problem in this sort of way, starting with wet sludge, would the energy that you could get out of it be sufficient to evaporate its water?—Oh, yes, I think so.

25537. It could be made a cycle, so to speak?—Yes, I think something of the sort has been done at the Dalmarnock works of the Glasgow Corporation in connection with the sewage disposal works there; I think they have a dryer in use, a sludge dryer of American origin, known as the "Cummer dryer," where the heat is utilised after passing from the destructor through the boiler, then through the sludge dryer, drying the sludge, which sludge is eventually disposed of as a fertiliser; something of the same sort was contemplated at Walthamstow, but the authorities dropped it on account of the initial expense.

25538. Have any experiments been going long enough to enable one to say that taking the cost as a whole, that is to say the cost of drying the sludge, and the gain by heat in burning it, the selling value of the clinker, that they balance out to give anything in the shape of a profit on the right side, or if there is a loss what sort of loss would be suffered?—Well, that entirely depends upon the circumstances, sir; if it is possible to fully utilise the resulting power, and to sell or use the whole of the clinker, and also if the works are embarked upon with reasonable economy, without putting too much money into the chimneys and buildings and so forth, I should say it is possible to operate such a works without incurring any loss; I should not like to say, taking the thing as a whole, that it is possible to make a profit; although there are some few isolated instances where a net profit is actually being made, but not where sludge is being burned though; where we are dealing with house refuse alone.

25539. House-refuse; then, of course, the house refuse has not to be dried, the sludge has to be dried; which makes a difference?—Exactly so.

25540. Your impression is that it might be made if not to pay, at all events not to make a loss?—Self-supporting.

25541. From sludge alone?—Yes, sir.

25542. (*Major-General Carey.*) You have given the opinion in some cases that you have brought forward as typical that they prove the case for combined sewage and destructor works conclusively; that is only when the conditions are favourable; that is to say, when the sewage works are not too far away from the destructor, or if the destructor is near the sewage works the cost of cartage of refuse has to be considered?—Exactly; I think there I refer to certain specific conditions; that is where the destructor is adapted to boilers which already exist, as in the case of Aldershot in Hereford, which I have quoted, a chimney also existing, so that part of the expense which would be incurred in connection with an entirely new plant is saved; therefore, the capital expenditure being low, it is an easy matter to very quickly recoup it.

25543. Then if the destructor is some way from the town, and the sewage works are some way from the town, the cost of carting the refuse would always be a very serious item?—Yes, that is so, but in some towns something might be done on the lines to what has been done at Hereford. There they only use 10 tons of refuse at the sewage works for providing the whole of the power that they want every day, and they arrange to collect that 10 tons of refuse as near to the sewage works as possible, 10 tons of refuse only being rather less than half of the total collection of house refuse in Hereford, something might be done in that direction in other towns where less than the whole of the refuse would be sufficient to provide the whole of the power required.

25544. Would you advocate the provision of a destructor for sewage sludge only in cases where the sewage outfall works are a long distance from the town?—Well, I think one has to take into account the calorific value of the sludge; in every case of that kind it is a matter which ought to be looked into and considered on its merits.

25545. I am now referring to a case where the sludge cannot be disposed of readily at a profit, or there is some difficulty in getting rid of it at all?—Well, it is pretty difficult to answer a question of that kind generally, sir, because if we take the case of Bolton, where it does not pay to take house refuse to the destructor; they are very well situated for getting a supply of dust coal, fine coal for burning with the sludge instead of house refuse, Bolton, of course, being quite near to collieries; but if we speak generally, if we take a case quite the opposite—some of the towns down here in the south—it might be very costly to get dust coal; that naturally puts a different complexion on the case entirely.

25546. The clinker that is produced is not at all satisfactory, that is the clinker produced from the destruction of the sludge and refuse?—I have never heard any complaint about it, sir, when the refuse and sludge is burned satisfactorily.

25547. It makes a close hard clinker?—Oh, yes, sir; in fact, I think in every case that I have tabulated here from recent information there is only one or two towns at most where they have any difficulty in getting rid of the clinker, that is where they are not able to record an actual revenue from the clinker.

25548. (*Mr. Stafford.*) Do they use the clinker in bacteria beds?—Oh, yes, sir, in quite a number of cases I cannot give you the number off-hand, but I have them all tabulated here and I could very soon give them to you if you like to have them.

25549. They do not find it too soft, do you think?—Well, there has been soft clinker on the market in years gone by, but I do not think one often hears a complaint now about soft or unsuitable clinker.

25550. They find it entirely suitable for bacteria beds?—Oh, yes; enormous quantities are being sold now, sir.

25551. You are referring now to the places you know of where it is in use?—Yes, I have all of them before me now, the information being tabulated during the last fortnight.

25552. Are these places where the sludge is burned?—Some of them.

25553. And the clinker that is produced is not a friable clinker?—No.

25554. You are speaking of all the places that you have got on that list?—I have about forty of them here. Of course, there are only three or four of them where sludge is being destroyed with refuse, but even in these cases clinker is being used or sold with one exception.

25555. You have personal experience of all those forty places?—Not of every one of them.

25556. How many of them would you say you have personal experience of?—Half of them, perhaps.

25557. In those twenty places you say the clinker is quite satisfactory?—I should say so; yes, sir.

25558. (*Sir William Ramsay.*) Is it not possible that the demand for clinker will cease; I mean, the renewal of the bacteria beds does not require to be very frequent, and at present when bacteria beds are being put up in large numbers there is a great demand for clinker; but after a little, surely that will cease?—That is so, but then you are speaking only of that particular outlet for clinker; there are various outlets—paving, flags, bricks, concrete, mortar.

25559. (*Mr. Stafford.*) But where the sludge is pressed there is bound to be a certain amount of lime in the clinker?—Oh, yes.

25560. And if there is lime in clinker will it not be very friable?—Well, we have not noticed that difficulty. I have seen unsatisfactory clinker when sludge is being burned, and I have seen very satisfactory clinker; in fact a clinker which the uninitiated man would hardly be able to tell from clinker produced from house refuse alone.

25561. Some of the clinker at some of those places is unsatisfactory?—I have seen it unsatisfactory, but not in any very large quantity.

25562. But your experience is that it is a useful clinker for bacteria bed purposes?—Yes, sir.

25563. (*Colonel Harding.*) Where it is unsatisfactory do you attribute it to the presence of the lime used in pressing?—No, I should not be inclined to put it down to that altogether; I should rather be inclined to put it down to the unsatisfactory working of the destructor; that is, the destructor has not been operated at a continuously high temperature, or in other cases where far too much refuse has been rushed through the cells without giving the material proper time for cremation, or without giving the residuum proper time to become hard and vitrified.

25564. When you tell us you have met with cases where the clinker product has been unsatisfactory, you do not mean to convey that it was unsatisfactory because of the addition of sludge, but it was unsatisfactory for other reasons?—I certainly do not mean to convey that it was unsatisfactory entirely owing to the fact that sludge was being burned.

25565. That is rather what we want to get at: does the burning of sludge in connection with the refuse injure the quality of the clinker?—I should say, generally speaking, it does not, if the two classes of material are being properly destroyed; that is if the destructor is being intelligently handled.

25566. Then you think it is quite practicable to make a good vitrified clinker from a mixture of refuse and sludge cake?—Yes, sir, I do; but I do not think that the average clinker which is produced from sludge and refuse would be equal to the very best clinker that is produced from refuse alone.

25567. Then the addition of sludge does increase the difficulty?—It does increase the difficulty, to some extent.

25568. Now, reverting to the case which you mentioned to us where, I think at Bolton, the coal dust has been used to burn the sludge cake without town refuse at all?—Yes, sir.

25569. Are you able to give us what would be the cost of a process of that kind: the cost per ton of burning sludge cake by the addition of inexpensive fuel such as coal dust to the extent of one cwt. to the ton?—Yes, sir, I think I can give you that; I have got the average labour cost per ton destroyed at Bolton, I think for the last twelve months for the year 1904—0d. per ton.

25570. Was that when they were using the coal dust, and not the town refuse?—It covers the whole year during which time they burned at some times refuse and at other times coal dust.

25571. In fact you are unable to give us the separate figures bearing upon the experimental process?—I could not give you the separate figures; I can only give you the average over the year.

25572. Do you think from your general knowledge it would be financially practicable to burn sludge cake with coal dust, provided coal dust were available in that immediate neighbourhood?—Yes, sir.

25573. You think it is quite practicable?—Oh, yes it can be done.

25574. And you can make destructors to deal with sludge and the coal dust in that way?—Yes, sir.

25575. And you do not anticipate that the burning of such a mixture would cause nuisance?—No, not at all.

25576. In fact there is no instance that you know of where this is being done?—As I have already explained it seems to be done at Bolton only periodically.

25577. Only occasionally; but you do not know any plant which has been constructed for the purpose of dealing with sludge ake with such addition only as might be necessary to enable it to be burned without town refuse at all?—I do not know any case, sir, where those particular conditions have arisen requiring the constant utilisation of coal dust instead of refuse.

TABLE No. 1.

Appendix to Mr. Goodrich's Evidence.

1 Town.	2 Population.	3 System of Sewage Disposal.	4 Daily average volume of sewage pumped.	5 Average height of Lift in feet.	6 Brief description of Pumping Plant.	7 Make and type of Destructor.	8 Number and type of Boilers.	9 Working steam pressure, in pounds.	10 Number and type of supplementary coal fired Boilers.	11 Periods when such are used.	12 Average weight of refuse destroyed daily.	13 Average number of working hours daily.
			Gallons.								Tons.	
Aldershot	18,500	Bacteria beds first contact, second streaming.	900,000	20	Horizontal H.P. condensing engines 12-H.P. each, 2·8″ centrifugals.	Meldrum's front fed.	2 Cornish.	45	None	None	14	16
Brentford	15,546	Precipitation and bacterial.	600,000	41	2·25-H.P. horizontal pumps.	Manlove's top fed.	2 Babcock and Wilcox.	125	Destructor boilers arranged for coal firing.	Sundays and nights.	20	24
Bolton	170,000	Chemical precipitation, land filtration.	—	—	Tangyes' 10″ steam ram sludge pumps.	Meldrum's Beaman and Deas top fed.	Ditto	120	Ditto	For starting destructor fan.	48	12
Cambridge	50,000	Intermittent filtration.	2¾ millions, average 1904.	43	2 Hathorn Davy compound engines.	Manlove's mechanically charged.	3 Babcock and Wilcox.	80	Ditto	Week-ends and during storms.	26	24
Dartford	21,000	—	1½ millions	28–30	Pumps, 22″ cylinders × 30″ stroke, 18 p.m.	Meldrum's regenerative top fed.	1 Lancashire.	200	—	—	11	8–9
Eastbourne	48,500	Sea discharge	Approx. 350,000	20–26	Air compressors and ejectors.	Manlove's top fed.	3 Babcock and Wilcox.	70	2 Lancashire.	Sundays and during cleaning.	44	21
East Ham	120,000	Tank treatment.	3¼ millions	26	2 centrifugals, total capacity 12 millions daily.	Meldrum's regenerative front fed.	1 Babcock and Wilcox, 1 Lancashire.	125	None	None	30	24

Eccles	36,000	Sedimentation tanks, land and bacterial.	2 millions	23	2. 36-H.P. engines, 1. 90-H.P. engines, 3 centrifugals.	Ditto	2 Lancashire.	135	None	None	28	24
Epsom	14,000	Septic tanks, broad irrigation and contact beds.	600,000	33	Combined H.S. engines and centrifugals.	Ditto	2 Cornish.	120	None	None	10	8
Elland	11,000	Chemical precipitation.	Gravitation	16 sludge pump.	8″ pump coupled to 12-B.H.P. motor.	Meldrum's front fed.	1 Lancashire.	180	1 Babcock and Wilcox.	During destructor cleaning.	10 tons refuse, 5 tons sludge.	6 hours summer, 10 hours winter.
Gosport	30,000	Septic tanks, sea discharge.	400,000	10–29	18 ejector stations.	Horsfall's back fed.	1 Galloway.	80	1 Galloway.	Ditto every 4 weeks.	30	24
Hereford	21,382	In a state of conversion from intermittent downward filtration to bacterial.	1½ millions	37	2 differential pumps, each 60-H.P.	Meldrum's front fed.	2 Galloway.	70	None	None	10	10½ and Sundays 7½.
Heywood	26,000	Tanks, filters, land filtration, bacterial.	—	—	—	Meldrum's regenerative front fed.	1 Lancashire.	140	None.	None.	20	24
Hyde	33,000	Septic tanks and continuous bacterial filters.	1 million	10	3 pulsometers, sludge pump, 2 engines, etc.	Ditto	Ditto	100	1 Cornish.	Sundays only.	24	24
Huddersfield	100,000	Chemical precipitation and single contact.	—	—	—	Horsfall's back fed.	2 Lancashire.	80	—	—	No refuse	24
Leamington	27,000	Broad irrigation.	800,000	80	Beam engines, and plunger pumps.	Horsfall's top fed.	1 Babcock and Wilcox.	50	3 Lancashire.	1 Lancashire in summer, coal cost £2 9s. per week.	35	12 summer and 24 winter.
Leyton	110,000	Precipitation and chemical treatment.	125,000 out of 3 millions.	—	3·7″ centrifugal pumps.	Meldrum's Beaman and Deas top fed.	3 Babcock and Wilcox.	112	2 Galloway.	Rarely used	75 refuse, 70 pressed sludge.	24

Mr. Walter Francis Goodrich, Assoc. Inst. Mech. E.

15 June 1905.

TABLE No. 1.—*cont.*

1 Town.	2 Population.	3 System of Sewage Disposal.	4 Daily average volume of sewage pumped.	5 Average height of Lift in feet.	6 Brief description of Pumping Plant.	7 Make and type of Destructor.	8 Number and type of Boilers.	9 Working steam pressure, in pounds.	10 Number and type of supplementary coal fired Boilers.	11 Periods when such are used.	12 Average weight of refuse destroyed daily.	13 Average number of working hours daily.
			Gallons.								Tons.	
Loughboro - - - - - -	25,000	Mechanical precipitation and broad irrigation.	1 million	24	Condensing engines and centrifugals.	1 Coltman and 2 Manlove's top fed.	1 Elephant and 1 Babcock and Wilcox.	80	—	—	12–14	24
Luton - - - - - - -	36,404	Broad irrigation.	1,686,000	113·4	Horizontal H.P. condensing engines and double acting pumps.	Horsfall's back fed.	2 Lancashire.	40	2 Lancashire.	1 Lancashire always used except when pumping low.	23	24
Lytham - - - - - - -	8,500	Sea discharge	from 150,000 to 1 million.	25	1·8″ compound, 1·5″ single centrifugals.	Meldrum's regenerative front fed.	1 Cornish.	120	None	None	12	24
Manchester (Withington)- - -	40,000	Tanks, bacteria and double contact.	2 millions	18	4 Tangye centrifugals, 4 Archer engines.	Ditto	2 Lancashire.	160	None	None	25 30	24
Newmarket - - - - - -	10,688	Bacterial and land.	250,000 dry weather flow.	23	Horizontal engines, centrifugals and compressors.	Manlove's top fed.	1 Babcock and Wilcox.	80	1 Cornish.	During destructor cleaning.	10	4
Radcliffe - - - - - - -	26,000	Precipitation and filtration.	400,000	50	2·30-H.P. horizontal engines.	Meldrum's regenerative back fed.	1 Lancashire.	120	None	None	13	9
Rotherham - - - - - -	58,000	Settling tanks, filter beds, broad irrigation.	Mostly gravitation.	—	Air compressor, and ejectors.	Manlove's top fed.	1 Multitubular	80	—	—	50	24
Royton - - - - - - -	15,500	Tanks, polarite filters, land.	375,000	20	1 double acting pump.	Warner's top fed.	1 Multitubular 1 Lancashire.	80 130	—	—	14	24

Salisbury - - - -	20,000	Septic tanks, bacterial, continuous flow.	2¼ millions	12–14	Worthington pumps.	Horsfall's back fed.	2 Babcock and Wilcox.	110	Destructor boilers arranged for coal firing.	About 40 tons coal per year.	18–20	24
Stafford - - - -	21,000	Chemical precipitation, intermittent land filtration.	7,000,000	36	2 Horizontal H.P. non-con. engines and 3 throw pumps.	Manlove's mechanically charged	Ditto	100	Ditto	—	14	16
Shipley - - - -	26,500	Bacterial	691,524 dry weather flow.	47	1·9″ centrifugal 1·7″ ,, direct coupled to motors.	Meldrum's regenerative front fed	1 Lancashire	160	—	—	21	10
Southampton - - -	114,000	Settling tanks	3 millions	20	Worthington pumps.	Manlove's top fed	3 Babcock & Wilcox	60	1 Lancashire.	When refuse is insufficient	40	24
Stourbridge - - -	17,000	Broad irrigation.	850,000	30	Beam engines	Horsfall's back fed	1 Lancashire	150	2 Cornish.	—	20	24
Taunton - - - -	22,000	—	850,000	Half gravitation half 25	2·10″ Gwynne centrifugals.	Ditto	1 Babcock & Wilcox	70	1 Marshall loco type.	Week-ends, and when short of refuse	20	24
Walthamstow - - -	105,000	Chemical precipitation, broad irrigation	300,000	20	60-H.P. horizontal engine and 2 centrifugals.	Meldrum's regenerative top and front fed	2 Lancashire	120	None	None	Refuse 40 sludge 20.	24
Watford - - - -	33,500	Broad irrigation	1¼ millions.	84 ft. } 35 ,, } 25 ,, }	Worthington's compressors and ejectors.	Meldrum's regenerative front fed	1 Lancashire	120	2 Lancashire.	One boiler 10 hours on Sunday, and 7 days quarterly	25	24
Winchester - - -	20,000	Ditto	700,000	100 ft. } 130 ,, } 150 ,, } 200 ,, }	2·40-H.P. beam engines 1. Worthington.	Manlove's top fed	2 Babcock & Wilcox	150	1 Lancashire.	When necessary	10–12.	24

TABLE No. 1—*cont.*

1 Town.	2 Population.	3 System of Sewage Disposal.	4 Daily average volume of sewage pumped.	5 Average height of Lift in feet.	6 Brief description of Pumping Plant.	7 Make and type of Destructor.	8 Number and type of boilers.	9 Working steam pressure, in pounds.	10 Number and type of supplementary coal fired Boilers.	11 Periods when such are used.	12 Average weight of refuse destroyed daily.	13 Average number of working hours daily.
			Gallons.								Tons.	
West Bridgford - - - - -	10,000	Bacterial and irrigation	200,000 dry weather flow.	40	Three throw horizontal pumps.	Warner's top fed.	1 Multitubular.	60	—	—	—	—
Weymouth - - - - - -	20,000	Sea discharge 2 miles out	800,000	22	3 Double acting horizontal pumps.	Meldrum's regenerative front fed.	2 Cornish.	120	1 Cornish.	Sundays and Bank Holidays only.	18	12
Slough - - - - - - -	12,000	Broad irrigation	300,000	30	2 Tangye horizontal and 1 centrifugal.	Meldrum's boiler furnaces.	3 Cornish.	2 at 45 1 at 80	—	—	2	12
Teddington - - - - -	16,000	Chemical precipitation and downward land filtration.	1¼ millions	35	6 Plunger pumps. One compressor, one sludge pump.	Ditto	2 Galloway.	70	—	—	5	24

No data to hand from Combined Destructor and Sewage Works at Bury, Ealing, Gorton, Glasgow, Nuneaton, Sudbury, Wakefield, Worthing.
Destructors are now in hand for Sewage Works at Twickenham and Wolverton. (All of Meldrum's Front Fed type).

June 9th, 1905

W. Francis Goodrich

TABLE No. 2.

A Town.	B Approximate weight of clinker produced daily.	C How clinker is utilised.	D Actual value of clinker per annum.	E Basis of calculation.	F Actual *Labour cost* per ton of refuse destroyed.	G Weight of sludge cake (if any) daily produced and destroyed.	H Percentage of moisture in sludge.	I Actual saving in coal cost per annum due to destructor.	J Basis of calculation.	K Actual saving in refuse cartage cost per annum (if any).	L Average destructor repairs, cost per annum.	M Total cost of destructor.
Aldershot	4 tons	Bacteria beds at works.	(1,300 tons) per year £218.	Previous cost.	9d.	—	—	£350	Previous coal cost.	—	18s. only in 5 years.	£1,200
Brentford	7½ tons	Sold	£25	3d. per load	about 1s.	—	—	—	—	—	—	£8,200
Bolton	33 per cent.	Bacteria beds at works.	—	—	10d. refuse and sludge.	16 tons	55 per cent.	£234	Coal cost	—	£14	—
Cambridge	8 tons	Bacteria beds, etc.	—	—	1s. 3d.	—	—	—	—	—	About £60	£17,933 including pumping station, buildings, land and chimney.
Dartford	—	—	—	—	10d. to 1s.	—	—	—	—	—	—	—
Eastbourne	30 per cent.	—	Approx. £50	6d. per load	—	—	—	—	—	—	New plant, practically nil.	£6,800 including buildings and inclined roadway.
East Ham	10-12 loads	Percolating filters.	—	—	1s. 7·7d.	—	Unpressed about 95 per cent.	About £1,000.	Previous coal cost.	—	Ditto	£12,600 including buildings, etc.
Eccles	9 tons	Bacteria beds and concrete.	£400	2s. 6d. per ton.	11½d. including flue cleaning.	—	—	£350	Ditto	£150	Nil, in 1½ year's working.	£4,500 including clinker crushing and screening plant.

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Mr. Walter Francis Goodrich, Assoc. Inst. Mech. E.

15 June 1905.

TABLE No. 2—*cont.*

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Elland	4½ tons	Levelling up ground.	—	—	9·4d. including wheeling sludge.	5 tons	Unpressed 95 per cent.	—	—	—	Nil, in 1½ year's working.	—
Epsom	28·7 per cent.	Bacteria beds at works.	£186	Previous contract 6s. 9d. per ton at station.	1·1d.	—	—	£370	Say 1 ton of coal daily	—	Ditto	£4,510
Gosport	10 tons	For new roads.	Estimated £150.	3,000 loads at 1s.	about 1s.	—	—	Estimated £400.	—	—	Estimated £50, including tools.	£1,700 destructor and roadway only.
Hereford	32 per cent.	Bacteria beds at works and mortar.	—	—	1s.	—	49 per cent. direct from presses, 34 per cent. after 3 weeks' atmospheric exposure.	£400	Previous coal cost.	—	Total in 8 years, £34.	£806
Heywood	5 tons	Bacteria beds at works.	—	—	1s. 2d.	—	—	—	—	—	—	£5,000
Huddersfield	30 per cent.	Ditto.	5s. per cubic yard.	Estimates obtained for similar material.	9d.	25 tons	Unpressed 90 per cent. pressed 60 per cent.	Nil	—	—	—	£665
Hyde	30 per cent.	Ditto.	—	—	1s. 9d.	—	—	50 per cent. of coal bill.	—	—	—	£7,000 including buildings.
Leamington	—	Sold for various purposes.	During 1903 and 1904, 5,303 tons at 1s.	—	—	—	—	At rate of £183 per annum during summer.	Previous coal cost.	*Increased* 8¼ per cent	£15	£6,310

Leyton	30 per cent.	—	—	—	1s. 10d., sludge and refuse.	70 tons	Pressed, 50–60 per cent.	£225	300 tons coal at 15s.	—	£150, but including engines, lift, &c.	£9,000, including engines, boilers, chimney and lift.
Loughborough	24 per cent.	Bacteria beds and road foundations.	£50	9d. per load	—	Air-dried in lagoons and sold to farmers.	—	£602	Previous coal cost.	—	No. 1=£60. No. 2=£5.	£1,400 each.
Luton	36 per cent.	Sold	—	6d. per ton	1s. 3½d.	—	—	Estimated £500.	Ditto.	—	Has only been at work 3 months.	Approx. £5,000.
Lytham	4 tons	Road foundations and mortar.	£70	—	8d.	—	—	£250 to £300.	Coal cost	—	Total, £3 6s. 0d. in 3 years.	£2,400, including buildings and chimney.
Manchester (Withington)	22 per cent.	Bacteria beds at works.	£456 5s. 0d	1s. per ton	1s. 7d.	—	—	—	—	—	—	£2,610
Newmarket	25–30 per cent.	Bacteria beds and road foundations.	1,000 tons at 1s. 6d.	—	1s.	Carted to arable land on farm.	—	£225	Calorific value of refuse as compared with coal.	Nil.	No separate account kept.	—
Radcliffe	3 tons	Bacteria beds at works.	—	—	10d.	—	—	—	—	—	£17 10s. 0d.	£3,300
Rotherham	17–20 tons	Tipped	—	—	1s. 1d.	—	—	—	—		£60 to £70.	£7,586, including land
Royton	—	Bacteria beds and road foundations.	—	—	1s. 1¼d.	—	—	—	—	—	£30	—
Salisbury	5 tons	Bacteria beds at works.	—	7s. to 11s. per ton paid previously.	1s. 3d.	—	—	—	—		No separate account kept.	About £3,000
Shipley	33 per cent.	Ditto.	—	—	1s. 1d., including flue cleaning.	—	—	About £200	150,000 units per annum, value £200.	—	—	—

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TABLE No. 2—*cont.*

A Town.	B Approximate weight of clinker produced daily.	C How clinker is utilised.	D Actual value of clinker per annum.	E Basis of calculation.	F Actual *Labour cost* per ton of refuse destroyed.	G Weight of sludge cake (if any) daily produced and destroyed.	H Percentage of moisture in sludge.	I Actual saving in coal cost per annum due to destructor.	J Basis of calculation.	K Actual saving in refuse cartage cost per annum (if any).	L Average destructor repairs, cost per annum.	M Total cost of destructor.
Southampton	13 tons	—	—	—	1s.	Taken to sea.	Unpressed 80–90 per cent.	—	—	—	£69 7s. 2d. in 1904.	—
Stafford	3½ tons	Used for various purposes, some sold.	—	—	1s. 4d. including maintenance.	—	—	—	—	—	No separate account kept.	£4,006
Stourbridge	30 per cent.	—	—	—	7d.	—	—	Anticipated £250.	Previous coal cost.	—	Maker's period of maintenance only just expired.	—
Taunton	33 per cent.	849 cubic yards used for bacteria beds in 1904.	—	—	8½d.	—	—	£118 16s. 7d. during 1904.	Ditto.	—	—	£4,000
Walthamstow	18 tons	—	—	—	About 1s.	20 tons	65 per cent.	Estimated £650.	Ditto.	—	Has only been at work 3 months.	About £9,000, including building, chimney, etc.
Watford	33 per cent.	Sold for bacteria beds, etc.	£101 3s. 9d. in 1904.	—	1s. 4d., including supervision.	—	—	£783 18s. 2d. in 1904.	Ditto.	—	Working 1¼ years only.	£6,800, including building and chimney.
Winchester	—	Road foundations and paving flags.	—	—	—	—	—	Probably 50 per cent. of coal bill.	—	—	—	£2,350

West Bridgford - -	about 25 per cent.	Sold for filling and road foundations.	£17 in 1904	6d. per load	1s. 6d.	—	—	£150	Coal cost	—	£10 in 1½ years.	£5,600 approx., including engines, building, chimney.
Weymouth - - - -	5 tons	Sold for bacteria beds, etc.	£75	—	11d.	—	—	£376	Previous coal cost.	£230	£2 10s. in 1½ years.	About £4,000.
Slough - - - - - - -	8 cwts.	Concrete flags and asphalte paving.	—	—	extra cost 3d. per load.	—	—	£104	Ditto.	1s. per load of refuse destroyed.	One year nil.	£110
Teddington - - - - -	—	Sold for various purposes.	£15	300 loads at 1s.	—	—	—	About £400	Ditto.	—	Trifling 5 years.	About £150.

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TABLE No. 3.

——	Nuneaton.	Sudbury.
Population	30,000	7,109
System of Sewage disposal	Bacteriological	Septic tank and double contact beds.
Average daily volume of Sewage pumped	900,000 gallons	100,000 gallons.
Average height of lift	19 ft.	65 ft.
Brief description of pumping plant	Compound horizontal engines and three throw pumps.	Worthington triple expansion condensing double-acting engines.
Make and type of Destructor	Meldrum's Regenerative Front Fed.	Meldrum's Regenerative Front Fed.
Number and type of boilers	2 Lancashire	2 Cornish.
Working steam pressure	70 lbs.	80 lbs.
Number and type of supplementary boilers	1 Lancashire	None.
Periods when such boilers are used	During Destructor cleaning	When refuse is insufficient breeze is burned in Destructor.
Average weight of refuse daily destroyed	18 tons	4 tons in winter. 3 tons in summer.
Number of working hours daily	24	6
Approximate weight of clinker produced daily	—	1 to 1¼ tons
Weight of sewage sludge, if any, destroyed daily	–	—
Percentage of moisture in sludge	—	–
Actual saving in coal cost per year due to Destructor	—	£80 to £100.
Basis of calculation	–	Coal cost.
Actual labour cost per ton of refuse destroyed	8¾d.	8d.
How clinker is utilised		Bacteria beds.
Actual value of clinker per annum		£100
Basis of calculation	—	500 tons at 4s. local value.
Saving in cartage cost, if any, due to disposing of refuse at Sewage Works	Nil	Nil.
Average repairs cost to Destructor per annum	£10	Nil in 2 years.
Total cost of Destructor plant	£2,000, including buildings	£2,000, minus building and chimney.

Mr. W. E. ADENEY, D.Sc., recalled; and further Examined.

25578. (*Chairman.*) This is a paper you hand in to us dealing with the question of the quantitative determination of the "strength" of sewage, tank liquor, etc. ?—Yes. The question of the quantitative determination of the strength of crude sewage, tank liquor and sewage effluents, is an extremely complex one. Those constituents, which are commonly associated with refuse waters, can no doubt be estimated by the ordinary methods with sufficient accuracy, but the results, when obtained, do not afford the information required, at least so far as they can be interpreted in the light of present knowledge.

Perhaps the best way of approaching the question is first to gain a clear conception of the character of the information which is required.

For all practical purposes a crude sewage may be regarded from the point of view of the requirements for its purification. It is known that the chemical changes which bring about the purification are the result of the activities of living organisms and not of direct chemical action. The purification of sewage therefore involves the consideration of physiological as well as of chemical processes; and the information required concerning the sewage, or sewage effluent, in order to estimate its strength, is its behaviour when undergoing aërobic bacterial fermentation.

Only two of the physiological processes which are set up by the organisms during aërobic fermentation are of importance, so far as regards the strength of a sewage or of a sewage effluent. They are digestion (enzymic action), and respiration (oxidation) under aërobic conditions.

The other physiological processes, constructive metabolism, and excretion, need not be considered in detail. Their total effect can, if desired, be indirectly estimated as I shall show later on.

I may quote in explanation of my meaning the results of some experiments which I have made with dilute solutions of known strength and composition. The substances which were employed may be regarded as types of those to be met with in crude sewage and other waste liquors; and the organisms effecting the fermentation may also be regarded as typical of those to be met with in river water. The solutions may therefore be regarded for the purposes of study as sewages, with the added advantage that their compositions and strength were accurately known. The results of these experiments have been published in a paper entitled "Chemical Changes attending the aërobic Bacterial Fermentation of Simple Organic Substance" and published in the Proceedings of the Royal Irish Academy, vol. 25, section B, 1905.

A feature of importance in connection with the experiments I am about to quote need some reference. It is the manner in which a supply of atmospheric oxygen was ensured during the fermentations. In those cases in which it was only desired to study the initial stages of them, the oxygen dissolved in the water was relied upon as sufficient. When, however, it was necessary to study the results of the later stages of the fermentation, a known and sufficient volume of air was left in the vessel containing the solution, the volume of which was also known. The solutions were also well shaken from time to time during the progress of the experiments, in order to prevent the bottom layers of the solutions from being de-oxygenated. The strength of the solutions furthermore were adjusted so as to be about equivalent to the organic carbon content of a crude sewage.

TABLE I.—*Fermentation of Rochelle Salt.*

ANALYSES giving the oxygen consumed, and the inorganic products formed, by the respiratory changes exerted by water organisms during the earliest and later stages of their development and activity in solutions containing ·141 grm. Rochelle salt (equivalent to 44·64 cc. CO_2), and ·1 grm. each, sodium carbonate, potassium phospbate, and potassium chloride, per litre.

The gases are stated in c.c. at N.T.P., and the organic nitrogen and ammoniacol nitrogen in grammes, per litre.

No.	Description of Experiments.	Dissolved gases.			N. as NH_3	Organic N.	Oxygen absorbed from air in flask.	Respiratory changes.	
		CO_2	O_2	N_2				CO_2 formed.	O_2 absorbed.
40	Solution when freshly made - -	22·45	6·89	13·63	0·0	·0003	—	—	—
41	Portion of the solution 18 days later.	23·47	6·89	13·70	0·0	—	—	1·02	—
42	Another portion similarly kept - -	26·58	5·45	13·57	0·0	—	—	4·13	1·44
43	Another portion similarly kept - -	30·11	3·52	13·69	0·0	—	—	7·66	3·37
44	Another portion kept 20 days - -	34·10	1·63	13·59	0·0	—	—	11·65	5·26
45	Another portion also kept 20 days -	36·78	0·44	13·61	0·0	—	—	14·33	6·45
46	A portion of No. 43 after further keeping for 38 days in contact with 409·2 cc. air per litre.	44·18	6·38	14·46	trace	—	10·7	21·73	11·21
47	A portion of 45 kept in contact with 507 cc. air per litre for 15 days longer.	50·01	6·01	13·83	trace	—	15·06	27·56	15·94
48	Portion of 44 kept in contact with 497·7 cc. air per litre for 43 days longer.	55·29	6·14	15·11	trace	·0002	19·2	32·84	19·95
49	Portion of 42 kept in contact with 430·8 cc. air per litre for 47 days longer.	55·78	5·98	14·63	trace	·0002	18·27	33·33	19· 2
50	Portion of 41 kept in contact with 241 cc. air per litre for 95 days longer.	56·4	4·76	14·99	trace	·00025	18·9	33·95	20·93

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On carefully examining the results recorded for Nos. 48, 49 and 50, which represent the completion of the fermentation, it will be seen that only about 75 per cent. of the carbon originally present in the Rochelle salt was oxidised to carbon dioxide, and further that the substance was oxidised in two equal stages.

During the first stage the proportion of oxygen absorbed to carbon dioxide formed was as 1 : 2, and during the second stage as 3 : 4.

These proportions show that the two stages of oxidation which Rochelle salt undergoes when fermented broadly consist of (1) a partial oxidation to sodium potassium malate, carbon dioxide, according to the equation

$$2C_4H_4KNaO_6 + 2O_2 = C_4H_4KNaO_5 + 4CO_2 + 2H_2O + KNaO$$

and (2) a complete oxidation of the malate to carbonic dioxide and water, according to the equation

$$C_4H_4KNaO_5 + 3O_2 = 4CO_2 + 2H_2O + KNaO.$$

The volume of carbon dioxide actually formed on the completion of the fermentation of the Rochelle salt was, as shown by experiment 50, 33·95 cc. The volume of oxygen required to form this, according to the above two equations, is 21·22 cc. The volume actually found by experiment was 20·93 cc.

We learn, therefore, from these experiments that when Rochelle salt becomes dissolved in water and suffers aërobic bacterial fermentation, about 75 per cent. of it undergoes respiratory changes or oxidation, while 25 per cent. is taken up by other physiological processes for the formation of constructive material, and certain coloured organic substances of an excretory nature.

TABLE II.—*The Fermentation of mixed Rochelle Salt and Urea.*

ANALYSES giving the total atmospheric oxygen consumed, and the products formed by the respiratory and enzymic changes exerted by the organisms during the earliest and later stages of their development and activity in solutions containing 0·225 grms. urea (equivalent to 83·7 cc. carbon dioxide, and 0·105 grms nitrogen), and 0·141 grms. Rochelle salt, per litre.

No.	Date.	Dissolved gases.			Nitrogen as NH_3 grs.	Respiratory changes.		Enzymic changes.	
		CO_2 c.c.	O_2 c.c.	N_2 c.c.		CO_2	O_2	CO_2	NH_3
10	At commencement - - -	19 60	5 34	11·25	0·0002	—	—	—	—
11	Six days later - - - -	32 04	0·19	10·69	0·0003	12·36	5·15	0·08	0 0001
12	Nine days later - - -	32·65	0 00	10·79	0·0007	12 65	5·34	0·40	0·0005
13	Twelve months later - -	33·38	0·00	11 05	0·0009	13 14	5·34	0·56	0 0007
14	Seven days later - - -	70·25	4·74	13·31	0·0220	33·11	22·75	17·54	0·022
	Atmosphere of flask in No. 14 :—								
	At commencement - - -	0 00	160·84	606·34	—	—	—	—	—
	At conclusion - - - -	0 00	138 09	601·88	—	—	—	—	—

At first sight it would appear that the fermentative results obtained in the foregoing experiments are not comparable with those given in the first table of experiments, but on closer inspection they will be found to be precisely similar, so far as the respiratory or oxidation changes which the Rochelle salt suffered in the two sets of solutions are concerned.

Experimental proof is given in the paper from which these tables are quoted, to show that in these experiments the urea suffered no appreciable respiratory changes, but simply an enzymic change according to the equation

$$CON_2H_4 + H_2O = CO_2 + 2NH_3.$$

It is consequently possible to differentiate the products of the enzymic change of the urea from those of the respiratory changes suffered by the Rochelle salt, and these two sets of changes are distinguished in the table.

Thus the 0·22 grms. nitrogen as ammonia, which was formed in experiment 14 is equivalent to 17·54 cc. carbon dioxide, in accordance with the above equation. This leaves a volume of 33·11 cc. carbon dioxide as formed by the result of respiratory changes suffered by the Rochelle salt.

The volume of oxygen theoretically required for the formation of this volume of carbon dioxide by the complete oxidation of Rochelle salt, is 20·7 cc. The volume of oxygen actually absorbed in experiment 14 was 22·75 cc.

Thus the volume of carbon dioxide formed and of oxygen absorbed during the complete fermentation of similar quantities of Rochelle salt, both in the presence and absence of urea, may be taken as practically similar.

It is evident, therefore, that the introduction of urea into the solutions of Rochelle salt did not appreciably affect the fermentations which proceeded in them, so far as the respiratory changes were concerned.

The urea did, however, affect the fermentation in one very important particular. It enormously increased the rate of the fermentation. Thus the fermentation of the Rochelle salt in experiment 14 was complete in 7 days in the presence of urea, while in its absence the same quantity of Rochelle salt required at least 65 days for similarly complete fermentation (see experiment 49, Table 1).

TABLE III.—*Fermentation of Asparagine.*

ANALYSES giving the Oxygen consumed, and the Inorganic Products formed, by the Respiratory and Enzymic Changes exerted by Water Organisms during the earliest and later stages of their development and activity in Solutions containing ·123 grm. Asparagine (equivalent to 82·88 cc. CO_2 and ·026 grm. N), and 0·1 grm., each, Sodium Carbonate, Potassium Phosphate, and Potassium Chloride, per litre.

No.	Description of Experiments.	Dissolved Cases.			N as NH_3	Organic N	Oxygen absorbed from air in flask.	Respiratory Changes.			Enzymic changes. N as NH_3 formed.
		CO_2	O_2	N_2				CO_2 formed.	O_2 absorbed.	N as NH_3 formed.	
15	Solution when freshly made	17·62	6·94	13·89	·000	·026	—	—	—	—	—
16	Part kept for 3 days out of contact with air	19·02	6·33	13·74	·001	—	—	1·40	0·61	·001	—
17	Another part kept for 5 days	29·36	0·0	13·74	·013	—	—	11·74	6·94	·001	·012
18	Another part kept for 5 days	29·78	0·0	13·73	·013	—	—	12·16	6·94	·001	·012
19	Another part kept 5 days in contact with 122·4 cc. air per litre	39·23	3·35	14·42	·0155	—	12·3	21·61	15·59	·0035	·012
20	Portion of 16 kept 2 days in contact with 271·4 cc. air per litre	39·50	5·61	14·82	·0148	—	13·8	21·88	15·1	·0028	·012
21	Portion of 18 kept 3 days in contact with 186·3 cc. air per litre	49·83	3·18	14 28	·017	·008	19·8	32·21	23·6	·005	·012
22	Portion of 19 kept 3 days in contact with 356 cc. air per litre	60 95	3·89	14·49	·018	·0076	30·2	43·32	34·1	·006	·012
23	Portion of 17 kept 42 days in contact with 324·5 cc. air per litre	73·66	3·13	14·22	·0216	·004	38·0	56·04	41·8	·0096	·012
24	Portion of 20 kept for 43 days in contact with 631·5 cc. air per litre	74·63	4·87	14·37	·0216	·0044	42·6	57·01	44·67	·0096	·012
25	Another solution at commencement	20·56	7·18	14·26	·000	·026	—	—	—	—	—
26	Part kept 5 days out of contact with air	33·21	0·02	14·25	·013	—	—	12·65	7·15	·001	·012
27	Another part kept for 8 days	33·28	0·08	14·25	·013	—	—	12·72	7·08	·001	·012
28	Portion of 26 kept 22 days in contact with 304 cc. air per litre	76·81	2·79	14·98	·022	·004	40·0	56·25	44·4	·01	·012
29	Portion of 28 kept 23 days in contact with 536·3 cc. air per litre	76·50	6·77	14·40	·022	·004	6·6	—	2·6	—	—
30	Portion of 27 kept 48 days in contact with 561·4 cc. air per litre	74·13	5·30	15·12	·020	—	40·6	53·57	42·5	·008	·012

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It will be seen from this table that the whole of the asparagine was very rapidly changed by enzymic action into aspartic acid and ammonia, and that the respiratory changes were subsequently exerted upon the aspartic acid so formed, in accordance with the following equations:—

$$C_2H_3(NH_2)(CO.NH_2)(CO_2H) + H_2O = C_2H_3(NH_2)(CO_2H)_2 + NH_3 \quad (1).$$

$$C_2H_3(NH_2)(CO_2H)_2 + 3O_2 = 4CO_2 + NH_3 + 2H_2O. \quad (2)$$

From equation (1) it is seen that, as a result of hydrolysis one-half of the nitrogen in asparagine is retained in the product, aspartic acid, and one-half goes to form ammonia.

Since, in the case of asparagine, ammonia is the sole inorganic product of enzymic change, the whole of the carbon dioxide formed during its fermentation may be regarded as the result of respiratory changes.

The experiments recorded in the Table form a series illustrating different stages of fermentation from commencement to completion; and the course of the fermentative changes are best shown by the accompanying curves; thus, when the carbon dioxide and ammonia are plotted together, the course of change is represented by two straight lines, one showing the course of enzymic changes, the other the after-effect of respiratory changes upon the aspartic acid, the organic product of the first named changes. (*See* Appendix to Dr. Adeney's evidence, page 679).

The volumes of carbon dioxide formed and of oxygen absorbed are in the proportion of 4 : 3, which is in accordance with the above equation (2); and when they are plotted together, a straight line is also obtained.

It may therefore be concluded that the absorption of the greater part, if not of the whole, of the oxygen may also be regarded as due to respiratory changes.

The quantities of carbon dioxide and of ammonia which resulted from the complete fermentation of the solutions of asparagine employed are shown by the results of experiments 23 and 24 with the first solution, and by experiments 28 and 29 with the second solution. They may be taken to be 56·25 c.c., and 0·01 grm. nitrogen as ammonia, per litre. These quantities represent 67·9 per cent. of the carbon, and 72 per cent. of the nitrogen, in the asparatic acid formed by the hydrolysis of the asparagine.

Hence it may be concluded that asparagine, when fermented by water-organisms under aërobic conditions, undergoes complete enzymic change into aspartic acid and ammonia during the earlier stages of activity of the organisms, and that the aspartic acid subsequently suffers respiratory changes, which account for about 68 per cent. of its carbon and 72 per cent. of its nitrogen, the remaining 32 per cent. of the former and 28 per cent. of the latter being taken up by other physiological processes.

Table IV.—Fermentation of Albumose.

ANALYSES giving the Oxygen consumed, and the Inorganic Products formed, by the Respiratory Changes exerted by Water-Organisms during the earliest and later stages of their development and activity in Solutions containing 0·05 grm. dry Albumose, equivalent to 28·68 c.c. CO_2, and 0·0055 grm. N, and 0·1 grm. each, Sodium Carbonate, Potassium Phosphate, and Potassium Chloride, per litre.

No.	Description of Experiments.	Dissolved Gases.			N as NH_3.	Organic N.	Oxygen absorbed from air in flask.	Respiratory Changes.		
		CO_2.	O_2.	N_2.				CO_2 formed.	O_2 absorbed.	N as NH_3 formed.
31	Solution when freshly made	18·34	7·36	14·69	·00003	·0055	—	—	—	—
32	Portion kept 8 days out of contact with air	19·38	6·28	14·57	·0003	—	—	1·04	1·08	·0003
33	Another portion kept 7 days out of contact with air	20·97	5·01	14·63	·0005	—	—	2·63	2·35	·0005
34	Another portion kept 7 days out of contact with air	26·27	0·22	14·64	·0016	—	—	7·93	7·14	·0016
35	Another portion kept 9 days in contact with 118 c.c. air per litre	30·76	4·07	15·52	·0024	—	8·9	12·42	12·19	0024
36	Another portion kept 29 days in contact with 204 c.c. air per litre	40·50	3·80	14·19	·0041	—	19·5	22·16	23·1	·0041
37	A portion from 32, kept 31 days in contact with 310·6 c.c. air per litre.	41·06	4·75	14·22	·0042	—	21·3	22·74	23·91	·0042
38	A portion from 33, kept 51 days in contact with 419·5 c.c. air per litre.	40·85	5·49	14·35	·0044	—	20·7	22·51	22·57	·0044
39	A portion from 35, kept 31 days in contact with 189 c.c. air per litre	40·71	4·87	14·14	·0044	—	12·3	9·95	11·15	·002

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Albumose was taken as a type of albuminous substances, because it is easily dissolved, and readily undergoes fermentative changes. Egg albumen, on the contrary, is very difficult to ferment under the conditions of experiment employed in this investigation. Solutions of egg albumen undergo slight change only, the albumen being deposited as a thin iridescent film on the sides of the containing vessel, and remaining unoxidised.

It was anticipated that albumose, itself a product of enzymic change, would not suffer further change by such process, under the conditions of experimenting, and that consequently the inorganic products resulting from its fermentation would be entirely due to respiratory changes.

The details of the experiments, and the results obtained from them, will be found in Table IV. Different stages in the fermentation, from commencement to finish, are illustrated by the experiments.

On plotting together the carbon dioxide and ammonia formed, a practically straight line is obtained. An approximately straight line is also obtained when the volumes of carbon dioxide formed, and of oxygen absorbed, are plotted together; the volumes are also in the proportion of 1 : 1 approximately.

It is therefore evident that the oxygen absorbed, and the two inorganic products formed, in these experiments, were the result of respiratory changes.

The fermentation of the albumose was complete in the experiments 36, 37 and 38; and the carbon dioxide formed in each of these amounted to 22·16, 22·74, and 22·51 cc. per litre, and the nitrogen, as ammonia, to 0·0041, 0·0042, and 0·0044, respectively. The volumes of oxygen absorbed in these experiments were, respectively, 23·1, 23·91 and 22·57 cc.

The quantities of carbon dioxide and ammonia formed in these experiments account for about 78·5 per cent. of the carbon, and 76·5 per cent. of the nitrogen, originally present in the albumose.

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TABLE V.—*Fermentation of Asparagine and Rochelle Salt.*

Solution A contained 0·066 grammes asparagine, 0·141 „ Rochelle salt, 0·1 „ potassium phosphate. } per litre.

No. of Experiment.	Date of commencement and of conclusion of Experiment.	Nature of Experiment.	Co_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5	Remarks.
1	1894 March 6	Solution A, as above (in tap water) -	11·21	7·86	15·93	0.0	0·0	0 0001	
	„ 12	Same after fermentation - - -	26·73	0·05	16·13	0.0093	0·0	0 0	Liquid very turbid, but free from odour.
		Differences -	+15·52	− 7·81	—	+ 0·0093	—	—	
2	„ 12	Remainder of preceding solution, after fermentation, re-aerated, =A′ -	26·62	7·36	15·14	0·0095	0·0	0·0	
	„ 13	A′ after fermentation, - I.	37·16	1·52	15·30	0.0108	0·0	0·0	Ditto
	„ 14	Another bottle of A′ after fermentation from March 12, II.	40·15	0·05	15 16	0·0102	0·0	0·0	Ditto.
		Differences I.	+10·54	− 5·84	—	+ 0·0013	—	—	
		Differences II.	+13·53	− 7·31	—	+ 0·0007	—	—	
3	„ 14	Remainder of solution A′ (March 14) diluted with equal volume of distilled water and aerated = A′/2 - -	20.62	7 81	16·11	0 0032	0·0	0·0	
	„ 19	Same after fermentation - - I.	32·21	1·72	15·92	0·0045	0·0	0·0	Faint sour odour, turbid.
	„ 19	Another bottle of A′/2 after fermentation II.	32.01	1·56	15·89	0·0038	0·0	0·0	Ditto,
		Differences I.	+11·59	− 6·09	—	+ 0·0013	—	—	
		Differences II.	+11·39	− 6·25	—	+ 0·0006	—	—	
4	„ 19	Remainder of liquid from two preceding analyses mixed and aerated -	29·06	7·56	15·60	0·0040	0·0	0·0	
	April 12	Same after fermentation - - -	36·75	0.00	15·40	0·0056	0·0	0·0	No distinct odour.
		Differences -	+ 7·69	− 7·56	—	+ 0·0016	—	—	
5	„ 12	Remainder of preceding solution re-aerated - -	31·42	7·04	13·98	0·004	0·0	0·0	
	August 1	Same after fermentation - - -	35·22	0 0	14 10	0·0044	0·0015	0·0	Quite free from odour.
		Differences -	+ 3·80	− 7·04	—	+ 0·0004	+ 0·0015	—	
6	„ 1	Remainder of preceding solution diluted with an equal bulk of distilled water and aerated - -	17·033	6·11	12·67	0·0022	0·0009	0 0	
	1895 Jan. 4	Same after fermentation - I.	16·69	0 07	12·55	0·0	trace	0·002	
	„ 14	Another bottle of same after fermentation - II.	16·79	0·05	12·63	0·0	0·00016	0·00204	
		Differences I.	− 0·34	− 5·94	—	− 0·0022	− 0·0009	+ 0·002	
		Differences II.	− 0·24	− 5·96	—	− 0·0022	− 0·00074	+ 0·00204	

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Fermentation of Rochelle salt and Asparagine mixed.

The influence of the chemical characters of the fermentable matters upon the rate of fermentation has already been illustrated by the experiments with solution of Rochelle salt with and without the addition of urea.

The foregoing experiments with a solution of Rochelle salt and asparagine, which are quoted from my paper on "The Course and Nature of Fermentative Changes in Natural and Polluted Waters and in Artificial Solutions" (*Trans. Roy. Dub. Soc.*, 1895), show that, when these two substances are mixed together, the fermentation proceeds more rapidly than in solutions of either substance alone.

They also show the effect of dilution in retarding the rate of fermentation in an interesting way; compare experiments 2 and 3.

On referring to experiments 1 and 2, it will be seen that when the fermentation was well started it proceeded with great rapidity.

From the fact that at the stage of the fermentation represented by experiment No. 5, the commencement of the formation of nitrous acid is indicated, it may be assumed that the fermentation of the Rochelle salt and asparagine originally present in the solution was complete at about the end of experiment 4.

The volumes of oxygen absorbed, and of carbon dioxide formed, during each step of the fermentation represented by the experiments 1, 2, 3, and 4, and the ratios of one to the other, are given in the following table; the quantities of nitrogen as ammonia are also given :—

	CO_2	O_2	Ratios.	Nitrogen as Ammonia.
Experiment 1 - - - - -	15·52	7·81	2 : 1	0·0093
,, 2 - - - - -	13·53	7·31	1·85 : 1	0·0007
,, 3 (×2) - - - -	22·98	12·34	1·86 : 1	·0019
,, 4 (×2) - - - -	15·38	15·12	1 : 1	·0032
Totals - - - -	67·41	42·58	1·58 : 1	·0151

These figures show that the greater portion of the nitrogen in the asparagine was quickly converted into ammonia, so that it may be assumed that the asparagine was rapidly hydrolysed by enzymic action into aspartic acid and ammonia, just as in the case of the solution of asparagine unmixed with other organic substances. It then appears from the ratios of carbon dioxide formed to oxygen absorbed and also from the ammonia formed that the Rochelle salt and aspartic acid jointly suffered respiratory changes, intermediate organic products of oxidation being formed, which were further and completely oxidized at later stages of the fermentation.

The ratio of carbon dioxide and of oxygen, which would have been respectively formed and absorbed, had the two substances present in the solution been completely oxidised to carbon dioxide, water and ammonia, is 1.47 : 1.

67·41 cc. of carbon dioxide were formed on the completion of the fermentation. This volume represents 78·96 per cent. of the carbon originally present in the asparagine and Rochelle salt.

Apparently, from the quantities of ammonia shown by the experiments to have been formed, all the nitrogen originally present in the asparagine was converted into ammonia by fermentation. This, however, is probably only apparent. From the nature of the experiments the errors attending the ammonia determinations would in the aggregate be considerable.

The balance of the carbon originally present in the solution was no doubt taken up by other physiological processes already referred to.

The foregoing table also illustrates the fermentation of ammonia to nitrites and nitrates. It will be observed from the table that these bodies do not appear amongst the products of fermentation until the organic substances have been completely broken down, and when consequently the formation of carbon dioxide rapidly diminishes; and this sequence of chemical changes always occurs, so far as my knowledge and experience goes, during the aërobri fermentation of solutions of sewage or of other organic substances. Perhaps when the fermenting liquid is passed through a good percolating filter, in other words, when the bacterial activity and the supply of oxygen are very large in proportion to the fermenting matters present in the solution or sewage, it may not strictly hold, but there can be little doubt, from theoretic considerations, that it will be found to hold good for all practical purposes even under the special conditions obtaining in a good percolating filter.

An experimental investigation of the ammonia, or, as it may conveniently be termed, in contradistinction to the carbon stage, nitrogen stage of fermentation, will be found described in the volume of *Trans. Roy. Dub. Soc.*, already quoted, pp. 593-615.

I trust I have given enough experimental evidence to support the view, which my own knowledge and experience has strongly pressed upon my mind, that the adoption of the aeration method of analysis is a necessity for the accurate determination of the "strength" of a sewage or tank liquor, for the estimation of the quality of an effluent, and for the formulation of standards for effluents.

The results recorded in the foregoing tables are typical of the chemical changes which fermentative organic substances, including those to be found in sewage, undergo during aerobic bacterial fermentation; and they do not stand alone. They are confirmed by the results of the experimental investigations which have been published in the paper already referred to, and I may add by a large number of unpublished experiments.

It may not be possible to distinguish the products of enzymic actions from those of the respiratory process in a liquid of such complex composition as sewage, but a large number of experiments with sewage all go to show that the combined results are constant for similar volumes of the same sewage. In other words the organisms behave under true aerobic conditions as constant chemical factors, and the volumes of oxygen absorbed during fermentation, and the products of oxidation, only appreciably vary with the chemical composition of the organic contents of the fermenting liquid.

A little consideration will show that this assertion is by no means unwarranted. The experiments prove that 70 to 80 per cent. of the organic substances in the fermenting liquid are converted by oxidation and possibly also by hydrolysis into the inorganic products carbon dioxide, water and ammonia. Consequently only 20 to 30 per cent. can be taken up by the other physiological processes of construction and excretion. And it is only amongst the products of these two processes that distinct variations may be expected as a result of the activities of different species of organisms.

But experience shows that the products of these processes are unimportant, unless the water, into which the purified sewage is discharged, is used for drinking purposes, and then it, or the water to be drunk, must be subjected to such careful and thorough filtration that the separation of both organisms and excretory products will be ensured.

It may be well to note here that in the subsequent process of the fermentation of ammonia, the excretory matters will be more or less completely oxidised to carbon

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dioxide and nitric acid, Ample proof of this will be found in the paper above referred to.

To return to the question of the method of quantitatively determining the strength of crude sewage, tank liquor and effluents, it is evident that no method dependent upon direct chemical action can afford an accurate or satisfactory result, at least in the present state of our knowledge. What is required to be known is the volume of oxygen absorbed in the manner above described, and further, if the purification is to be very good, the volume of oxygen absorbed during the fermentation of part or whole of the ammonia remaining in the liquid after the fermentation of the organic substances.

All this information can, as I have shown, be obtained by the method I have employed. Fermentation, however, proceeds very slowly in the dilute solutions of the sewage which have to be employed to ensure aërobic conditions.

I have recently endeavoured to modify the method so as to obtain more rapid fermentations. My experiments, however, are not yet complete, but they have gone far enough to satisfy me that this can be effected, and the oxygen absorbed during the fermentative changes can at least be accurately determined by the employment of a small gravel filter of suitable construction. With the apparatus I have employed it has been possible to ferment a crude sewage, without previous dilution, and determine the oxgyen absorbed, easily within a working day.

The apparatus consists of a glass cylinder 55 to 57 mm. diameter, and a little more than a metre long. It was nearly filled with a fine siliceous and limestone river gravel, chiefly the former. It was found by sieving that the proportions of particles of different sizes were as follows—

1 part passed by a 1–40 inch sieve, and stopped by a 1–80 inch.

1 part passed by a 1–24 inch sieve, and stopped by a 1–40 inch.

3 parts passed by a 1–10 inch sieve, and stopped by a 1–24 inch.

3 parts passed by a 1–3 inch sieve, and stopped by a 1–10 inch.

1 part passed by a 3–4 inch sieve, and stopped by a 1–3 inch.

The capacity of the cylinder was 2,500 c.c. ; it was nearly filled with 3,830 grms. of the gravel, the specific gravity of which was 2·5. The volume of the gravel in the filter was therefore 1,535·7 c.c. Deducting this from 2,500 c.c., 964·3 c.c. is obtained as the volume of the air-spaces in the interstices of the filter.

The cylinder was closed at both ends by rubber corks fitted with the necessary tubes to regulate the supply of air, to gauge the pressure of it inside the filter, to regulate the flow of sewage into it, and finally to draw off samples of air and of filtered liquid for analysis.

The filter was made bacterially active by passing sewage through it from time to time for a week previously. It was then well washed with tap water and drained, and the volume of air in the apparatus was carefully determined by expanding the volume of the air in the filter apparatus by a known amount and observing the corresponding reductions of pressure, and making the necessary calculations from data thus obtained.

A sample of tank liquor from Belfast was allowed to flow slowly into the apparatus at the rate of 750 c.c. in two hours. The filtered liquid commenced to collect at the bottom 30 minutes after the commencement of the experiment. The flow of the sewage was stopped after 750 c.c. had passed into the apparatus, and the filter was allowed to drain for two hours. A sample of the air was then drawn from the interstices of the filter and on analysis it was found that oxygen had been absorbed at the rate of 143·3 c.c. per litre of sewage.

A sample of the tank liquor was diluted and set aside for fermentation by my ordinary method, as was also a sample of the effluent from the filter.

On the completion of the fermentation of the diluted sewage, and when its ammonia had been completely oxidised to nitric acid, the volume of oxygen absorbed was 238·5 c.c., and of carbon dioxide formed 191·6 c.c , per litre of tank liquor

On the completion of the fermentation of the sample of effluent and the oxidation of the ammonia therein, 99·2 c.c. of oxygen had been absorbed, and 16·44 c.c. carbon dioxide had been formed, per litre

On subtracting the volume of oxygen absorbed during fermentation of the effluent from the filter, 99·2, from that absorbed during the fermentation of the tank liquor, 238·5, 139·3 c.c. is obtained, and this volume represents the oxygen absorbed during the stage of fermentation which the tank liquor underwent in the filter. The volume given above for the direct experiment is 143·3 c.c.

A similar experiment was made with a second sample of tank liquor, but it was allowed to flow more slowly into the apparatus. The filtered liquid began to collect at the bottom in 56 minutes from the commencement of the experiment. Five hours afterwards a sample of air was drawn from the apparatus and analysed. The results showed that oxygen had been absorbed at the rate of 295·3 c.c. per litre of tank liquor.

By the dilution method, the tank liquor was found to require for complete fermentation, including the oxidation of the ammonium compounds to nitric acid, 366·8 oxygen per litre. At the same time 228 c.c. carbon dioxide were formed.

The effluent required for complete fermentation 71·5 c.c. oxygen per litre ; 13·08 c.c. carbon dioxide being at the same time formed. Hence, the volume of oxygen absorbed during the stage of fermentation which the tank liquor underwent in the filter was 295·3 c.c., the same as that obtained by the direct experiment.

Another portion of the same sample of tank liquor was passed through the filter on the suceeding day more quickly. 750 c.c. were allowed to flow on to the filter and disappear from the surface in 55 minutes. In 7 minutes from the commencement the filtered liquid began to collect at the bottom.

Three hours after the commencement, a sample of the air was drawn from the filter, and on analysis it was found that 265·6 c.c. of oxygen had been absorbed per litre of tank liquor. A portion of the filtrate was allowed to completely ferment, until all ammonia had been oxidised to nitric acid. It was then found that 98·8 c.c. oxygen had been absorbed and 51·70 c.c. carbon dioxide had been formed.

Thus the effect of passing the sewage more rapidly through the filter was a diminished purification. It is quite evident, however, that notwithstanding the short time during which the liquid was percolating through the filter, certainly not more than 10 minutes, the organic matters must have been nearly completely fermented.

In all the experiments, the filtered liquids were quite free from offensive odour ; they were yellowish-green in colour and slightly turbid.

These experiments must only be regarded as preliminary ones, but they are sufficient to show that the fermentation of the organic matters in a sewage may be effected in a bacterially active filter of suitable construction in the course of a comparatively few minutes, 30 in the case of the first quoted experiment ; and that the volume of oxygen absorbed can be determined without difficulty.

These experiments also afford an answer to the question as to how long a tank liquor should be in contact with a percolating filter for proper purification. The last experiment quoted was made with a rather strong tank liquor, and the results show that in 10 minutes a fair purification was obtained, while in 56 minutes the organic matters were completely oxidised.

The tank liquor employed for the first experiment was not quite so strong, and the results show that the organic matters were completely fermented after 30 minutes contact with the filter. It should be noted that both these samples of tank liquor contained colloidal matters in suspension.

The products of the fermentation in the foregoing filtration experiment were not directly determined, as the details of the method of experimenting had not been worked out. I am continuing my experiments for the purpose of ascertaining the best conditions for applying the principle of the method I have sketched for the purpose of rapid quantitative determination of not only the volume of oxygen absorbed by a sewage during the fermentation of its organic matters, but also of the products of its fermentation, carbon dioxide, ammonia and nitric acid.

Until this is done, it will be impossible, in my opinion, accurately to gauge the efficiency of any system of sewage purification, or to obtain accurate and reliable answers

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to several questions of great technical and public importance at the present time. I refer to such questions as——

(1) The minimum dimensions of percolating filter bed for the purification of a given sewage;

(2) The most advantageous thickness for a filter bed.

(3) The most advantageous size or sizes for filtering material.

(4) The maximum rate at which a given sewage may be passed through a filter to obtain satisfactory purification.

(5) The character of the solid matters discharged from percolating filter beds, as at present worked at some places.

Standards for Sewage Effluents.

I have already submitted my views on this question, and I need only now say that I am in favour of standards graduated to meet local circumstances and requirements.

There is one question of great practical importance, however, in connection with the formulation of standards, concerning which no information was available when I submitted my views to the Commission; I refer to the question of the rate of the re-absorption of oxygen by water exposed to natural conditions after it has been de-aërated by admixture with sewage matter.

Some experiments on this subject have recently been published in the *Trans. Roy. Dub. Soc.*, Vol. 8, Series 2, 1905, under the title of "Unrecognised Factors in the Transmission of Gases through Water." The paper has been reprinted in the *Phil. Mag.* March, 1905.

Glass tubes about 2 metres long and 18 millims bore were employed for the experiments here to be described.

The tubes were nearly filled either with distilled water or with sea-water, and warmed and exhausted as far as desirable by means of a mercury-pump. The corks closing the lower ends of the tubes were fitted with fine glass tubes to provide the means of attachment to the mercury-pump for exhaustion, and for drawing off samples.

After the gases in solution and in the air-spaces had been abstracted, the corks closing the upper ends of the tubes were removed, and the tubes were immersed to a depth of about 1300 mm. in a large water-jacket, which was kept cool by a constant flow through it of water from the main supply.

The object of the water-jacket was to prevent the formation of downward convection-currents, by keeping the lower portions of the water-columns in the tubes at a slightly lower temperature than the upper portions, which were exposed to the temperature of the laboratory.

In most of the experiments the surfaces of the water-columns were kept constantly agitated by means of currents of air drawn through their upper layers.

Slow currents of air were employed, at the rate of 1000 c.c. per hour.

In a few cases the surfaces of the water-columns were agitated by mechanically rotated glass stirrers, just dipping below the surface of the water. In these cases the experimental tube employed was of wider bore to allow of stirrers of a gridiron shape being used.

When the surfaces of the water-columns were left unbroken, the experimental tubes were loosely covered to protect their contents from dust.

The height of the columns of water were in nearly all experiments about 1800 mm. In all experiments the surfaces of the water were freely exposed to the air.

At the conclusion of each experiment, layers of the water of 100 to 200 mm. thick were drawn from different depths from the surface, and stored in tubes standing over mercury until they could be analysed.

The dissolved gases in these samples were extracted by boiling with a little sulphuric acid *in vacuo*.

Of the results of the analysis of the dissolved gases, only those for the nitrogen are recorded in the paper. These are expressed in c.c. at 0° C. and 760 mm. bar per litre.

The experiments show that the re-aëration of deep columns of de-aërated distilled water, where the surfaces exposed to the air are unbroken, is extremely slow.

The re-aëration of deep columns of de-aërated sea-water, although slow, is decidedly more rapid than that of distilled water. Thus—

No. 1.—Two tubes, each 1950 mm. long and 18 mm. bore, were filled to the height of 1800 mm. from the bottom, one with sea-water and one with distilled water, both being nearly nitrogen free, and were immersed in the water-jacket and kept undisturbed for 28 days. The temperature of the room varied between 16°·5 and 10° C., that of the jacket between 12°·9 and 8°·0 C. During the last week of the experiment the temperature of the room varied between 12° and 10° and that of the jacket between 9° and 8° C.

Distilled water saturated at 10° C. contains 15·37 c.c. N_2 per litre. Sea-water saturated at 10° C. contains 12·47 c.c. N_2 per litre.

Depth of Layer below surface.	Sea-water, Nitrogen c.c. per litre.	Distilled water, Nitrogen c.c. per litre.
1 to 200 mm. -	9·24	11·50
300 to 500 " -	8·96	11·10
800 to 1000 " -	8·91	8·43
1600 to 1800 " -	7·89	5·84
Before aeration -	1·51	1·55

It is important to note that the surface layers of the sea and distilled water, even after exposure to the air for 28 days, did not become saturated with nitrogen, and that the gas, as it was dissolved, did not remain concentrated in them, but passed through both the sea and distilled water more rapidly than it was dissolved at the surfaces exposed to the air. It is also noticeable that the passage of the dissolved nitrogen is decidedly quicker through the sea water than through the distilled water. Experiments are described in the paper which show that this passage of the dissolved gases vertically downwards through de-aerated sea or distilled water is a gravitational streaming effect of some kind. Hüfner has also noticed it, and has ascribed the cause of it to concentration currents. The experiments, however, which I shall quote, do not support this view, but rather suggest that the streaming is possibly caused by minute dust particles, or by other centres of condensation, possibly of an electrical nature, and that these bring about in some way a sufficient density of the dissolved or liquefied gases to render it possible for them to be drawn gravitationally downwards through the water.

When the surfaces of deep columns of de-aerated sea or distilled water are kept gently broken in such a way as to avoid mechanically disturbing the under portions of the columns, the water in both cases is rapidly re-aerated, the sea water much more quickly, however, than the distilled water.

No. 2.—Three tubes, each containing sea-water nearly nitrogen-free, were fitted with indiarubber corks and air-inlet and exit tubes, and were connected in series so that the same current of air could be drawn through the upper layer of each column of water to a depth of 200 mm., one after the other.

The air-current was a slow one, at the rate of about 1 litre per hour. The aeration was continued for 48 hours and then stopped. Samples of water were then drawn from each tube as before, and stored in glass vessels standing over mercury. The nitrogen determinations are given below. The tube in which the air-current first entered was marked 1, and the one it next entered 2, and so on. The air was filtered through glass-wool.

Temperature of room 12°·8 to 10°·0 C.
Temperature of jacket 8°·6 to 8°·3 C.
Sea-water at 10° C. contains 12·47 c.c. N_2 per litre.

Depth of Layer.	1.	2.	3.
1 to 200 mm. -	12·24	11·15	11·09
800 to 1000 ,, -	8·20	2·29	2·55
1600 to 1800 ,, -	8·13	2·18	2·54
Before aeration -	1·57	2·13	2·51

No. 3.—Similar to the experiment No. 2, with the exception that the air-inlet tubes dipped only 50 mm. below the surface. The air-current was filtered through glass-wool.

Temperature of room 13°·7 to 13°·5 C.
Temperature of jacket 8°·4 to 8°·5 C.
Sea-water at 13°.5 C. contains 11·67 c.c. N_2 per litre.

Depth of Layer.	1	2.	3.
1 to 200 mm. -	10·81	7·15	6·93
300 to 500 ,, -	10·60	1·61	1·52
800 to 1000 ,, -	9·36	1·65	1·56
1600 to 1800 ,, -	9·20	1·65	1·52
Before aeration -	1·75	1·63	1·51

No. 4.—Similar to experiment No. 2, with the exception that distilled water was used in place of sea-water.

Temperature of room 11°·5 to 11°·8 C.
Temperature of jacket 8°·5 to 9°·0 C.
Distilled water at 11°·8 C. contains 14·83 c.c. N_2 per litre.

Depth of Layer below surface.	1.	2.	3.
1 to 200 mm. - -	14·60	12·27	12·20
300 to 500 ,, - -	11·62	11·10	11·18
800 to 1000 ,, - -	4·18	4·20	4·48
1600 to 1800 ,, - -	3·54	3·05	3·20
Before aeration - -	1·55	1·73	1·97

No. 5.—Similar to No. 4, with the exception that the air-current was not filtered.

Temperature of room 12° to 10° C.
Temperature of jacket 8°·7 to 8°·5 C.
Distilled water saturated at 10° C. contains 15.37 c.c. N_2 per litre.

Depth of Layer below surface.	1.	2.	3.
1 to 200 mm. - -	13·81	12·77	12·64
300 to 500 ,, - -	12·20	11·17	11·08
800 to 1000 ,, - -	5·20	5·17	5·14
1600 to 1800 ,, - -	4·15	4·06	4·00
Before aeration - -	1·75	1·55	1·51

When de-aerated columns of sea and distilled water are aerated in the manner described in the foregoing experiments, it will be noticed that the results obtained for the former markedly differ from those found for the latter. In the case of the sea-water, the rate of aeration as a consequence of streaming was comparatively rapid in the first of the series of three tubes, but practically nil in the second and third tubes. It appears, therefore, from these experiments that something was taken from the air by the first water column in each series in addition to the ordinary atmospheric gases, and that very little reached either the second or third tubes.

In the case of the distilled water, it is seen from the results of the experiments that the cause of streaming was not concentrated in the first water column as with the sea water, but that, on the contrary, it equally affected the three water columns. It must be noted, however, that none of the columns of distilled water were so highly aerated as the first columns of the sea-water experiments. It may be inferred, therefore, that the streaming effect is greater in the case of sea-water than in distilled water. This fact may be explained by assuming that the sea-water, from the salts which it holds in solution, is able to make more use of the centres of condensation introduced with the air which is bubbled through it. When sea-water and distilled water are separately shaken up with air, the difference of behaviour of the two waters is, as is well known, very marked, it being easy to obtain a formation of small bubbles of air in sea-water to an extent quite impossible in distilled water.

There can be no question, from the experiments quoted, that if the air be completely washed, the surface of sea-water exposed to it will become saturated with nitrogen and oxygen, but no streaming effects will take place.

It is equally evident from these experiments that whatever may subsequently be discovered to be the true cause of the streaming, its effect in large volumes of sea-water and of river water under natural conditions must be of great importance, and of such dimensions that the effect of ordinary diffusion may in comparison be entirely neglected.

25579. (*Sir William Ramsay.*) This is a most interesting attempt to solve the sewage question by experiments with non-fermentable materials upon which I congratulate you ?—Yes.

25580. There are one or two questions on your evidence which occur to me; for example, I should like to ask if you have made many comparative estimates of permanganate absorption and dissolved oxygen absorption to see if they run concurrently ?—I have not made many, but I have made some, and I gave the particulars in the evidence which I gave before the Commission the first time I appeared before it, I think it was in 1898, which showed that there was really no comparison between the two.

25581. They do not run parallel ?—No.

25582. That is to say I presume the absorbed oxygen causes a certain amount of the substances to go into carbonic acid and water ?—Yes.

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25583. The permanganate only acts on another part of the substance or only a portion of it ?—The permanganate does not oxidise all the fermentable organic matter, and it is impossible to distinguish between the oxygen absorbed from permanganate by non-fermentable matter from fermentable matter.

25584. Of course, the same distinction is applied to albuminoid ammonia ?—Yes.

25585. Which you would regard simply as another means of applying the permanganate test ?—Yes.

25586. Experiments with Rochelle salt lead to this conclusion: that about 75 per cent. of it, when it undergoes aerobic bacteria fermentation, suffers respiratory changes or oxidation, while 25 per cent. is taken up by other physiological processes, chiefly, no doubt, for the formation of constructive material of the organisms and certain coloured organic substances of an excretory nature. This 75 per cent. of respiratory changes is ascertained, I presume, by the amount of carbon dioxide produced and by the amount of oxygen absorbed ?—Yes.

25587. And you regard that as a sign of respiratory changes ?—Yes.

25588. You regard the filter as an animal which is living? —Exactly, and that represents the percentage of carbon or the percentage of organic matter which is really oxidised, and accounts for the absorption of the dissolved oxygen.

25589. For, I suppose, any of the oxygen of this 25 per cent. ?—I should say it accounts for the greater portion of the absorption of the dissolved oxygen. No doubt a small portion is taken up by other physiological processes of the organisms.

25590. It introduces this question; the bacteria, no doubt, increase ?—Yes.

25591. But their total amount is so small that any absorption due to their growth may be neglected ?—Precisely.

25592. That is what it is ?—Yes, it is inappreciable compared with that taken up by the respiratory process.

25593. Then you think they act as manufacturers of something else which we do not know anything about ? —Yes

25594. Which are not part of organisms of the bacteria but which are made by them ?—Yes.

25595. Coloured matters ?—Yes.

25596. It is interesting to find that the application of urea to Rochelle salt makes no practical difference in the products except as regards rate. Have you any explanation to offer of the difference in rate ?—No, I have none whatever. The urea seems to act as a stimulant.

25597. As a kind of nitrification, in other words ?—Yes.

25598. To grease the wheels. Let me ask are these experiments old or comparatively new ?—They have only recently been published; I have made them from time to time, I think, since the year 1900.

25599. Would it be worth while adding some substances not so far degraded as urea; some substances such as uric acid, so to speak ?—Yes.

25600. In order to see whether they act as stimulants ? —Oh, I think so, decidedly; I think it most advisable that investigation of various combinations of organic substances or solutions of organic substances is most important.

25601. Might I point out an analogy: if you feed a dog on albumen alone, the white of an egg, he starves ?—Yes.

25602. If you give with that a certain quantity of stimulants, such as xanthin or sarcosin or bodies of that kind, the creature can live ?—Yes.

25603. No doubt with albumen alone there is a physiological action, but it is so slow that the albumen does not get distributed through his body as it should ?—Yes.

25604. If you give stimulating agents like sarcosin, etc., it makes the rate of absorption a much more rapid one, and the dog lives ?—Yes.

25605. In that way I think your experiments are extremely interesting from the point of view of urea; urea seems the kind of physiological agent which makes it go

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much more rapidly; if you were to use some such substances as are found in beef juice you could see whether they stimulate the reaction and make it take place?—Yes, that point of view much impressed this aeration method upon me in the examination of sewage: sewage is so indefinite in composition that you can only determine really the rate of absorption by actual experiment.

25606. And you are making what may be called a statistical experiment instead of a physiological experiment; instead of one dog you are making a similar experiment on hundreds of millions of bacteria?—Exactly. There is another interesting point as regards stimulation; that is the effect of humus in nitrifying ammonia solutions; it has a stimulating effect upon the nitrification.

25607. Apart from its furnishing food for the organisms?—Well, nitrification of ammonia and of nitrites can proceed without the addition of humus or of other organic substances to the solution; but if humus be present no doubt the humus is a food to the organisms; at the same time it stimulates the process and the rate of absorption of oxygen is accelerated.

25608. The fact that dilution retards the rate of fermentation is a very interesting one; have you been able to make out any relation between the rate of fermentation and the amount of dilution?—No; that, of course, is a question that ought to be worked out most thoroughly; it is most important.

25609. You said also that nitrites and nitrates do not appear amongst the products of the fermentation until the organic substances have been completely broken down, and when, consequently, the formation of carbon dioxide rapidly diminishes?—That is in aerobic fermentation.

25610. And then you go on to say when the fermenting liquid is passed through a good percolating filter, when the bacterial activity and the supply of oxygen are very large in proportion to the fermenting matters present in the solution or sewage, you think, then, that it is possible, if there is a very large excess of oxygen, for nitrification and the formation of nitrates to go on concurrently with the breaking down?—Well, I am doubtful whether it is concurrently.

25611. Do you think it is in layers?—I do not think there is any information which entitles us to say, in the form of definite information, but undoubtedly in effluents from filter beds nitrites do seem to appear at times before the complete breakdown of the fermentable organic matters. The proper explanation of that I am not prepared to offer. All my work has been confined to very dilute solutions of these organic substances. That is to say when both the organisms and the organic substances are small in comparison with the dissolved oxygen. Under these conditions I have never found a trace of nitrites or nitrates in the products of fermentation until the whole of the organic matter has been broken down.

25612. In a filter would it not be possible that that takes place in the strata?—It possibly does, but I think that is a question which wants to be investigated.

25613. It is suggested that in the top strata the organic matter would be broken down, and in the lower nitrification would take place?—Oh, yes, that would be so; I believe myself that is the probable explanation.

25614. You say that the rate of nitrogen fermentation with an effluent as discharged into a running stream, except under unusually unfavourable circumstances (you guard yourself there) would be too slow to endanger the aeration of the water of the stream. Does that refer to solids or merely to effluents free from solids?—Oh, to the effluents free from solids and in a high state of purification.

25615. If solids were present, of course, that would not hold necessarily?—No.

25616. You have not been making experiments, I suppose, on solids; you have always used solutions?—I have always used solutions; I have done a few experiments on solids, and I am most anxious to attack the question of the character of the solids discharged from the percolating filter; the determination of that character can only be done by application of the aeration method.

25617. Would it be possible to start with coagulated albumen only, such a substance as white of egg; to use that as an insoluble solid?—My experience of the true albumens is that they ferment extremely slowly; it is only after they have gone through a process of digestion that they readily ferment.

25618. What do you mean by digestion in this case?—What I mean of course, is the enzymic action, conversion into albumose.

25619. But suppose you were to take boiled white of egg—coagulated albumen, and exposed that to the action of bacteria, would it not be attacked?—Oh, yes, it would.

25620. But not rapidly?—No.

25621. Again, it would be possible to filter off the solids from the sewage effluent?—Yes.

25622. Wash them?—Yes.

25623. And redistribute them through water?—That, I think, would be a most desirable thing to do.

25624. Obviously one might know whether the solids play a very great part in causing absorption of oxygen at a later stage or not?—Yes; there can be no doubt that they do, when you remember the offensiveness of a sludge bank.

25625. (*Colonel Harding.*) I should like to ask, Dr. Adeney, one question, and that is, inasmuch as I notice that you have come to the conclusion from your interesting experiments that the aeration test is the best possible test for sewage and sewage effluents, can you suggest to us in what practical way such tests should be carried out? Suppose you have a sample of a sewage; you want to find out how much atmospheric oxygen is required for the aerobic fermentation and the fermentable matters in it, how would you just go to work to ascertain that?—It can be ascertained in one of three ways. (1) By diluting a portion of the sewage with thirty or forty times its volume of tap water, and determining the dissolved gases and ammonia before and after keeping in a full bottle out of contact with air for about twenty-eight days at about 60° Fahr. The volume of an atmospheric oxygen required for the aerobic fermentation of the organic matters in the sewage can then be calculated from the loss of oxygen. (2) By diluting the sewage with five times its volume of tap water, and keeping 500 c.c. of the well aërated dilution obtained in a stoppered bottle together with about half its volume of air, for ten to fourteen days at about 60° Fahr. The loss of oxygen due to fermentation of the organic matters will be ascertained by displacing the air in the bottle by means of mercury after the fermentation of the organic matters has been completed, and drawing the gases composing it into a gas-measuring apparatus, and determining the carbon dioxide and oxygen by absorption in the ordinary way. If at the commencement of the experiment the capacity of the bottle be ascertained and the temperature and pressure of the air left in the bottle be noted, the volume of oxygen can be calculated from the known composition of the air; then the loss of oxygen found after fermentation, plus the loss of dissolved oxygen suffered by the diluted sewage, will give the volume of oxygen required for the fermentation of the organic matters The loss of dissolved oxygen can also be calculated, and need not be directly determined. It will be the same fraction of the dissolved oxygen originally present in the aërated dilution, as the oxygen left in the air-space is of that originally present. (3) Or by the filtration method referred to in my statement. As there shown, the volume of oxygen required for the fermentation of the organic matters can be determined within a day. These three methods are all based upon the same principles. They differ only in the rapidity with which the fermentation is effected. It is advisable in the case of all three methods to determine the ammonia before and after fermentation, as well as the oxygen, since the completion of the fermentation of the organic matters is indicated by the commencement of the fermentation of the ammonia into nitrous and nitric acid. Hence if the ammonia in these experiments remains the same or begins to diminish, it is a fair indication that the organic matters have been fermented.

25626. You do not think the aeration test can be relied upon, and you suggest to us that the permanganate test and the test as to nitrification should be also carried out?—The aeration test when completely carried out can undoubtedly be relied upon. As regards nitrification I have given a good deal of evidence to show that if it be

found to have set in, it is a proof that the organic matters have been fermented ; and that it is important to know the volume of oxygen required to carry the fermentation of the sewage to this stage, since it is during this stage only that sewage matters can cause offensive putrefaction. As I have already explained the after fermentation of ammonia is not likely to cause any trouble in flowing water. I believe some such additional test to the aeration method as ammonia determinations, or as the permanganate test are necessary in ordinary practice as a protection against the use of antiseptics. These might conceivably be present in a crude sewage or in an effluent in sufficient quantity to prevent fermentation, or to retard it to such an extent as to render it inappreciable. Suspicion would at once be aroused if large quantities of ammonia were detected, or if the permanganate test indicated the presence of abnormal quantities of oxidisable matters for a good effluent, and no loss of oxygen were observable notwithstanding. There can be no question as to the course to be taken if they be found in a sewage or effluent. Their continued admixture must at all cost be stopped, if purification is to be carried on by bacterial action. In my remarks, so far, I have had in mind more particularly the question of the strength of crude sewage in relation to its purification. The question of the strength of effluents presents some special features, for in addition to their actual strength, it is necessary to know the rate at which they will cause absorption of dissolved oxygen after admixture with river or sea water. This aspect of the question is very important and at the same time does not present so much difficulty. For example, the aeration of the waters of a polluted stream may be determined on the spot by a suitable volumetric process, and a sample kept out of contact with air for forty-eight hours and the aeration again determined ; so also an effluent with or without previous dilution. But I should like to express the opinion that it would still be advisable to make from time to time a complete analysis by aerobic fermentation of every effluent and of the streams into which they are discharged, because only by such a course can exact knowledge of the character of the pollution of streams be obtained. I have in mind the examinations of some estuaries which Dr. Letts and I made for the Commission last August ; for instance, at the mouth of the Aire and the Ouse, notwithstanding the enormous pollution of these rivers in the higher reaches, we were surprised to find that the water at the mouth of these two rivers, just before conjunction, was distinctly aerated, and that after their conjunction and flowing into the Humber, the aeration of the waters of the Humber rapidly improved.

25627. Did you find these waters fully aerated ?—No.

25628. To what extent ?—Unfortunately, I have not got my notes, but I will afterwards add a note of the exact aeration.

The following are the results referred to expressed in parts per 100,000.

1904. August.	—	Oxygen in % of saturation.	Chlorine.	Nitrogen as :—			
				Organic.	Ammonia.	Nitrates.	Nitrites.
31	At mouth of R. Aire -	30·4	—	—	—	—	—
	Sample from same after being kept 13 days.	7·4	50·0	·037	·0001	·26	0·0
31	At mouth of R. Ouse -	24·4	—	—	—	—	—
	Sample from same after being kept 13 days.	6·7	5·0	·04	·0	·23	·007

25629. I notice you say that the re-absorption of oxygen from a quiescent surface is excessively slow ?—Very slow indeed.

25630. Re-aeration by the admixture of other matters ?—Yes, extremely slow.

25631. But probably where a stream is flowing or is disturbed by waves, the aeration would be rapid ?—Very much quicker.

25632. But returning for a moment to this question of the possibility of an aeration test by itself, is it not possible to take the sewage and to ascertain by simply adding a number of dilutions of tap water, and estimating the loss that takes place after a given time ; is it not possible to ascertain sufficiently nearly the amount of oxygen that would be required for the completion of the aerobic fermentation ?—Do you mean for sewage ?

25633. Yes, for sewage ?—No, I do not think so.

25634. Then I am afraid we must not, for sewage, rely upon the aeration test ; I rather gathered at first that you thought the aeration might be applicable, and was perhaps the best test that could be applied to ascertain the strength of sewage and sewage effluents ?—I should like to make myself quite clear in regard to the question of the reliability of the aeration, or, as it may be more correctly termed, perhaps, the aerobic fermentation method. There can be no doubt about its reliability. That, I think, has been well established. The point about which there is a doubt is the best way of obtaining a rapid aerobic fermentation. This is a question which is occupying, I believe, the minds of chemists interested in the subject at the present time. I am aware that both Dr. McGowan and Dr. Fowler have in mind the adoption of a small laboratory filter for the purpose. I have recorded a few experiments in the same direction in my statement. The results, I think, leave little doubt but that with a small filter properly fitted and worked, a sewage can be fermented in a comparatively few minutes, and that the oxygen absorbed and products formed can be rapidly determined. I have in progress some experiments which I commenced with a view of determining the best way of working the filter which I have described in my statement. I regret they are not in a sufficiently advanced state to quote here. I trust, however, to describe them in full in the report upon the Pollution of Tidal Waters which Dr. Letts and I have in preparation for the Commission.

25635. As in crude sewage, you have a large quantity of fermentable matter you think the change would be too slow to rely entirely upon the aeration test ?—Oh, no, sir ; not to rely upon it ; it would be too slow to regard it as a process suitable for common use in the laboratory ; you could rely upon it.

25636. That observation would apply to sewage effluents would it ?—Yes ; but there you are also concerned with the rate of absorption.

25637. Aeration of the small quantity remaining would probably make that a practical test, would it ?—Oh, undoubtedly.

25638. The difficulty is simply in applying the aeration test to a crude sewage ; I understood you to say that the complete fermentation would be too slow to enable us to consider that test as a practicable one ?—I am afraid I have not made my meaning quite clear. What I have had in my mind is the necessity of accuracy in determining from time to time, by a chief of a department or a chief officer, the real strength of a sewage, the real character of an effluent. That, so far as my experience and knowledge goes, can only be determined by the methods that I have described ; but I do not think I am justified in suggesting those methods at the present time for ordinary use by

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analysts, because they take too long to perform and to watch; therefore, I have this reservation; but the reservation does not in any way affect the value of the method as an accurate method; there can be no question about that; it does affect the value of the method in so far as it can be carried out in common analytical practice. Hence my endeavours to hasten the process of fermentation by the use of a filter, and so render the aeration method available as an ordinary laboratory method.

25639. Then do you think a laboratory experiment with a sort of percolating filter would be of value for testing the amount of oxygen that would be required?—I have not the least doubt it would be of very great value.

25640. (*Sir William Ramsay.*) Do you know Mr. Scot Moncrieff's portable apparatus for doing this?—No, I do not know.

25641. (*Colonel Harding.*) But if an apparatus in the nature of a small percolating filter with a standard material—let me put it for instance, half inch marbles or something of that kind—that one could rely upon repeating the experiment under like conditions in various places?—Exactly.

25642. Do you think that that would give, by the passage of a sewage through it, a good deal of the information that you are wanting?—Yes, I think so.

25643. Then with regard to the other interesting suggestion you made to us just now, have you yourself made any experiments at all in the direction of taking a small quantity of sewage in a vessel, the air contents of which are known to you, and causing that to act, shall we say, as a churn for a given time, to note the changes of fermentation that would take place?—Yes. I have made some experiments to test this suggestion, but the results are not so encouraging as those I have obtained with the filter.

25644. (*Sir William Ramsay.*) I only want to ask you is there anything else you wish to add?—With regard to the question of field work I did not complete what I wished to say with reference to the Rivers Aire and Ouse. I told you that Dr. Letts and I made some aeration tests at the mouths of those rivers, and found the waters were to a certain extent aerated but not saturated. We collected the samples, and preserved them, and found after keeping them out of contact with the air for about a fortnight that the aeration had nearly disappeared, but that the fermentation that was going on was a pure nitrification. There were really no signs of breaking down of organic matter, so that these rivers, the Aire and the Ouse, which we know to be very heavily polluted by sewage matters of one kind or another, had practically self-purified themselves at the time of our visit, August 1904, so far as fermentable organic matter was concerned, when they had reached their respective mouths. We also determined the aeration of the Thames at Chapman's Lighthouse, and it was considerable. We found that on keeping samples from the surface and from the bottom of the river at this point that they lost nearly the whole of their dissolved oxygen, and at the same time showed no sign of nitrification; so that although the Thames water at the Chapman appeared to be better, in a less polluted condition, than the waters at the mouths of the Aire and the Ouse, it was found when the waters were kept that the Thames at the Chapman was more polluted with organic matters than either of the other two rivers.

25645. Is it not possible that the nitrate ferments were absent in the Thames water?—I do not think so. The samples did not contain enough ammonia to account for the loss of oxygen by nitrification. We also examined some of the water at Woolwich, and we made a determination of the dissolved gases the day after they were collected through the kindness of Dr. McGowan in his laboratory, and also made a dilution of the sample which we took with four times its volume of tap water. We found, even with that dilution, on keeping for about a fortnight, a considerable de-aeration had taken place, but no indication of nitrification, so with a simple experiment like that it was quite possible to form an opinion as to really what ought to be done with the sewage which was discharged into the Thames, in order to prevent this de-aeration. The purification should certainly be ten times as good as it is. That is an opinion you can venture to express on the results obtained by the aeration method.

25646. Whereas in the case of the Ouse and the Aire you think the purification had been quite sufficient?—By the time the river water had reached their mouths, and under dry summer weather conditions, yes. It seems to be of the greatest possible importance, if the Commission will allow me to express this opinion, that field work should be done on these streams which are known to be heavily polluted. For instance, I think the Thames should be most carefully examined by the aeration method and the oxygen absorption to determine the exact degree of pollution which the sewage, as it is discharged into the Thames at the present time, is causing. I think valuable information could be obtained in that way, because the river and its conditions afford such a great and instructive object lesson. Similarly such rivers as the Ribble, the Mersey and Irwell, the Ouse and the Aire, if carefully examined, would afford results which would be most valuable object lessons in showing what has been done by natural conditions and agencies with the sewage discharged into it, and what is necessary to relieve those rivers from over pollution.

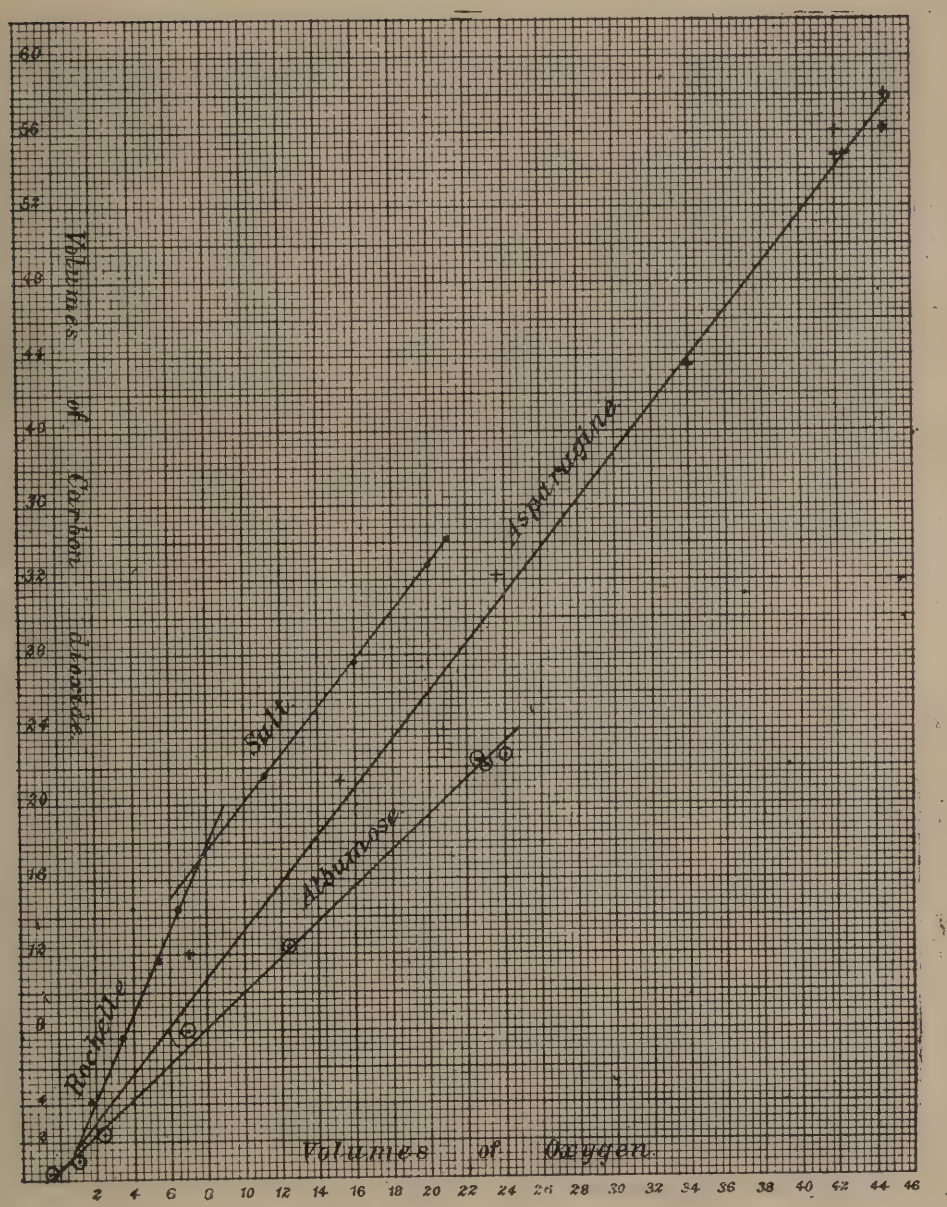
25647. Would you regard it as advisable that a bacterial examination should also take place?—Oh, undoubtedly; I think all chemical work should be carried on side by side with the bacteriological; there are so many problems on the bacterial side of the question which require working out and they can only be worked out, it seems to me, from a combination of workers from both the chemical and the bacteriological sides.

25648. Those are the points you wish to bring before us; is there anything else?—No, sir.

25649. Then I have the pleasant duty of thanking you for having taken the trouble to come?—I would only like to add, I have mentioned some experiments that I have in progress, I shall be very happy to furnish Mr. Willis with a copy of the results if the Commission would like me to.

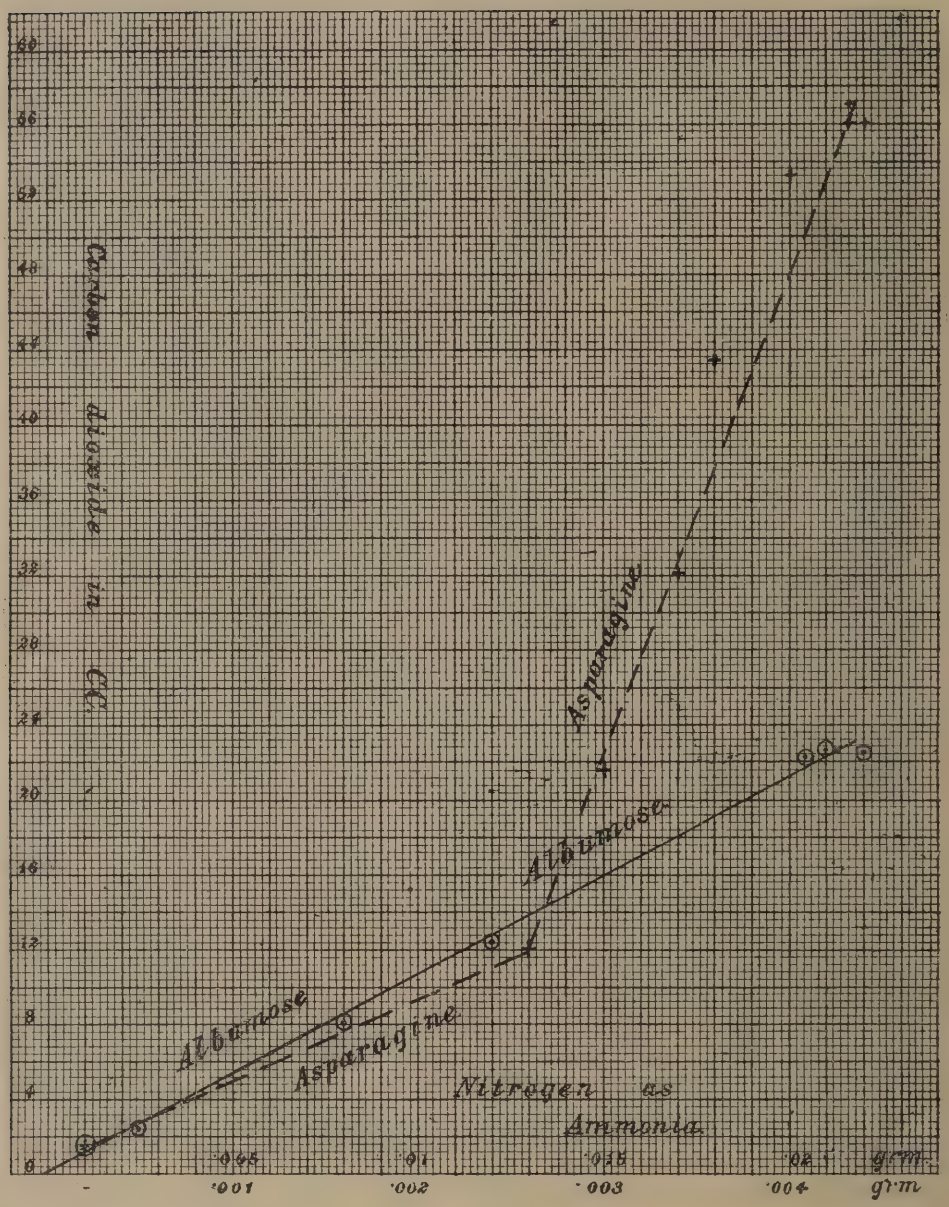
25650. When they are worked out, yes, thank you?—Yes.

APPENDIX TO DR. ADENEY'S EVIDENCE.



Curves showing the ratio of CO_2 formed to O_2 absorbed in the aërobic fermentation of very dilute solutions of Albumose of Asparagine and of Rochelle Salt.

APPENDIX TO DR. ADENEY'S EVIDENCE.



Curves showing the ratio of CO_2 to NH_3 formed in aërobic fermentation of very dilute solutions of Albumose and of Asparagine.

EIGHTY-FIRST DAY.

Friday 16*th June*, 1905.

PRESENT.

The Right Hon. THE EARL of IDDESLEIGH (*Chairman*), presiding.

Major-General CONSTANTINE PHIPPS CAREY, C.B., R.E.
Colonel T. W. HARDING, J.P., D.L.
Sir WILLIAM RAMSAY, K.C.B., F.R.S.
Mr. T. J. STAFFORD, F.R.C.S.I.

Mr. F. J. WILLIS (*Secretary*)

ALSO PRESENT.

Dr. A. C. HOUSTON.
Dr. GEORGE MCGOWAN.
Mr. G. B. KERSHAW.

Mr. FRANK SCUDDER, F.I.C., F.C.S., recalled; and further Examined.

Mr. Frank Scudder, F.I.C., F.C.S.

16 June 1905.

25651. (*Chairman.*) You have kindly supplied some particulars with reference to chemical analysis as applied to sewage and sewage effluents?—Yes.

CHEMICAL ANALYSIS AS APPLIED TO SEWAGE AND SEWAGE EFFLUENTS.

The Report to the Royal Commission on methods of chemical analysis presented by Messrs. McGowan, Floris, and Finlow (*see* Supplementary Volume, Part V., presented with the Fourth Report of the Commissioners) has naturally attracted my attention, and I should like to make the following observations thereon:—

1. "*Oxygen absorbed*" *from an acid solution of Permanganate of Potash.*

The object of using this test is to differentiate the quality of various organic matters in a sewage effluent by means of fixed time limits (*see* Minutes of Evidence, Interim Report, Vol. II., Q. 3608, and Table 14). The method of carrying out the test, and the effect of modifying the ratio of permanganate to sewage effluent has been investigated in my laboratory and numerical figures as to the results obtained from a large series of sewage effluents derived from a variety of purification processes are to be found in the Journal of the Society of Chemical Industry, 31st May, 1898, Vol. XVII.

Dr. McGowan and his colleagues have used in their experiments a permanganate solution ten times as strong as that used by me. The advantages, if any, for this modification are not set forth, nor are any results given which bring out a clearer differentiation of the quality of the organic matter than by the method which has usually been adopted. On the contrary, Dr. McGowan admits that unless the sewage effluents are very impure, the weak solution gives more accurate results (*see* page 40 of Supplementary Volume referred to).

Dr. McGowan presents twenty-eight grains of oxygen in the form of permanganate to each gallon of sewage effluent, whereas it is usual to present only five or ten grains according to the quality of the effluent.

Error due to manipulative skill is more marked with Dr. McGowan's method, inasmuch as an error of one-tenth of a cubic centimetre of the sodium hyposulphite solution in titrating is equivalent to 0·0387 milligramme oxygen, which multiplied by the factor 2·8 gives an error on either side of 0·108 grain oxygen absorbed per gallon of effluent.

The following experiments were made in order to compare the results derived from the two methods of procedure.

Following Dr. McGowan's method, 25 cc. of the sewage effluent were used in each test.

10 cc. Sulphuric acid (90 parts water to 10 parts acid).
10 cc. $KMnO_4$ solution = 0·010 gramme oxygen.
25·84 cc. $Na_2S_2O_3$ solution = 0·010 „ „
1 cc. „ „ = 0·000387 „ „

10 milligrammes oxygen × 2·8 = 28 grains oxygen per gallon of sewage effluent.

In the Mersey and Irwell method, 70 cc. of the sewage effluent were used in each test.

10 cc. sulphuric acid (75 parts water to 25 parts acid).
50 cc. $KMnO_4$ solution = 0·005 gramme oxygen.
31 cc. $Na_2S_2O_3$ „ = 0·005 „ „
1 cc. „ „ = 0·000161 „ „

In the case of experiments 25 and 26, however, 20 cc. sulphuric acid and 100 cc $KMnO_4$ solution were added.

The sulphuric acid should always be tinged pink with permanganate. This precaution is not referred to by Dr. McGowan.

TABLE 1.

EXAMINATION OF SEWAGE EFFLUENTS.

TABLE showing results of Three Minutes and Four Hours Oxygen Absorbed Tests as used in the Laboratory of the Mersey and Irwell Joint Committee compared with results obtained by the method recommended by Dr. McGowan.

Results expressed in grains per gallon.

	Name of Authority.	Date. 1904.	Time.	State of weather.	Method of purification.	3 minutes test.		4 hours test.		Remarks
						Weak. $K.M_nO_4$.	Strong. $K.M_nO_4$.	Weak. $K.M_nO$.	Strong. $K.M_nO_4$	
1	Heywood Corporation (Heap Bridge)	Dec. 1	2 p.m.	Fine.	Land.	0·07	0·17	0·16	0·28	Clear and colourless. No sediment. No smell.
2	Ashton in Makerfield U.D.C.	Dec. 5	2.40 p.m.	Showery.	Tanks, filters, land.	0·06	0·11	0·17	0·22	Clear and sparkling. No sediment. No smell.
3	Crompton U.D.C. (Cowlishaw)	Dec. 12	3 p.m.	Fine.	Tanks, filters, land.	0·19	0·33	0·17	0·33	Clear and colourless. Trace of sediment. No smell.
4	Stretford U.D.C.	Dec. 19	2 p.m.	Foggy.	Land.	0·11	0·05	0·17	0·05	Clear and colourless. No sediment. No smell.
5	Hayfield U.D.C.	Dec. 12	11.45 a.m.	Showery.	Tanks and land.	0·12	0·17	0·22	0·50	Clear and colourless. No sediment. No smell.
6	Chapel-en-le-Frith R.D.C.	Dec. 19	11.30 a.m.	Frost.	Tanks and land.	0·11	0·28	0·24	0·33	Clear and colourless. No sediment. No smell.
7	New Mills U.D.C.	Dec. 12	1 p.m.	Showery.	Tanks, filters, land.	0·15	0·33	0·27	0·33	Faint turbidity. Trace of sediment. No smell.
8	Abram U.D.C.	Dec. 5	1.30 p.m.	Fine.	Tanks and filters.	0·13	0·33	0·32	0·38	Clear and colourless. Trace of sediment. No smell.
9	Littleborough U.D.C.	Dec. 6	2.50 p.m.	Fine.	Tanks and filters.	0·17	0·17	0·33	0·22	Clear and sparkling. No sediment. No smell.
10	Hindley U.D.C. (Platt Bridge)	Dec. 5	3.45 p.m.	Showery.	Tanks and filters.	0·16	0·33	0·35	0·38	Almost clear and colourless. No sediment. No smell.
11	Disley R.D.C.	Dec. 19	2 p.m.	Frost.	Tanks and land.	0·11	0·22	0·37	0·39	Clear and colourless. Trace of fungus sediment. No smell.
12	Little Hulton U.D.C. (Ellenbrook)	Nov. 30	12.50 p.m.	Slight snow thaw.	Tanks and filters.	0·17	0·53	0·39	0·65	Faint opalescence. No sediment. No smell.
13	Little Lever U.D.C.	Dec. 7	1.30 p.m.	Showery.	Tanks and filters.	0·09	0·22	0·41	0·22	Clear. Sparkling. No sediment. No smell.
14	Salford Corporation	Dec. 20	12.45 p.m.	Foggy.	Tanks and filters.	0·20	0·45	0·51	0·81	Clear and colourless. No sediment. No smell.
15	Milnrow U.D.C.	Dec. 6	1.15 p.m.	Fine.	Tanks and land.	0·25	0·11	0·56	0·61	Faint turbidity. Trace of grey sediment. Faint smell.
16	Haslingden, Rawtenstall and Bacup J.D.C.	Dec. 8	12.20 p.m.	Frosty.	Tanks, filters, land.	0·25	0·28	0·56	0·75	Slight turbidity. Trace of sediment. Slight smell.
17	Farnworth U.D.C.	Dec. 7	2.30 p.m.	Showery.	Tanks and filters.	0·28	0·39	0·62	0·73	Slight turbidity. Grey sediment. Faint smell.
18	Tyldesley U.D.C.	Nov. 30	3 p.m.	Slight snow thaw.	Tanks and filters.	0·34	0·75	0·68	0·98	Almost clear and colourless. Trace of grey sediment. Faint smell.
19	Gorton U.D.C.	Dec. 20	3 p.m.	Foggy.	Tanks and storm filters.	0·33	0·39	0·78	1·15	Almost clear and colourless. Trace of brown sediment. No smell.
20	Gorton U.D.C.	Dec. 20	3.15 p.m.	Foggy.	Tanks and filters.	0·40	0·56	0·91	1·31	Almost clear and colourless. Trace of fungus sediment. No smell.
21	Leigh and Atherton J.S.B.	Dec. 21	12 noon.	Dry.	Tanks and land.	0·49	0·70	0·99	1·31	Slight brown turbidity. Little sediment. Slight smell.
22	Manchester Corporation	Dec. 19	3.45 p.m.	Foggy.	Tanks and filters.	0·64	0·87	1·26	1·37	Almost clear. Trace of grey sediment. Very faint smell.
23	Radcliffe U.D.C.	Dec. 7	11.30 a.m.	Showery.	Tanks and filters.	0·55	0·70	1·31	1·71	Turbid brown liquid. Brown sediment. Sewage smell.
24	Whitefield U.D.C.	Dec. 1	4 p.m.	Fine.	Tanks and land	0·59	0·70	2·04	3·36	Faint turbidity. No sediment. Slight smell.
25	Leigh and Atherton J.S.B.	Dec. 21	11.30 a.m.	Dry.	Tanks and storm filters.	1·60	1·79	3·07	3·69	Brown turbid liquid. Trace of brown sediment. Sewage smell.
26	Salford Corporation	Dec. 20	12.15 p.m.	Foggy.	Tanks.	2·03	2·43	4·59	5·26	Brown turbid liquid. Brown sediment. Slight smell.

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From these results it is seen, first, that the four hours' test with weak permanganate solution passes twenty-one samples out of twenty-six. With strong permanganate eighteen samples are passed. Second, the curve with strong permanganate does not run parallel with the weak permanganate curve. Third, this difference becomes more marked with the three minutes' test, and the use of a strong permanganate solution is not so satisfactory as a weak one.

With regard to the "at once" permanganate test, it does not possess any advantages over the "three minutes'" test, which is commonly followed, nor is any evidence given in favour of modifying the time limits usually employed. Indeed, Dr. McGowan admits that 'probably the "three minutes'?" test is better than the "at once" test."

2. *Determination of Free and Saline Ammonia.*

Dr. McGowan, on page 12, recommends that the strong standard solution of ammonium chloride should be weighed when put aside and again weighed before any further liquid is taken from it for dilution, in order to ensure that there has been no sensible evaporation "through" the stopper. This is a precaution quite unnecessary to adopt, and it is procedure that does not commend itself to me, inasmuch as it has not been shown that any loss has been observed to take place in a well-fitting glass-stoppered bottle.

The determination of the ammonia correction in the distilled water used is unnecessarily enlarged upon, and the procedure described by Dr. McGowan for ascertaining this is cumbersome. In theory, of course, the procedure is accurate, but in practice it would be making a mountain of a molehill.

The method of nesslerising, which is the important point in the whole determination, is not described, and to attempt to work with 1 or 2 cc. of a sewage, as Dr. McGowan suggests, is, in my opinion, carrying the test too far and putting it on a very unstable foundation.

With reference to the use of carbonate of soda and its hydrolysing action upon the organic matter of a sewage effluent, I am unable to confirm Dr. McGowan's statement on page 13 that: "The glass of the distilling vessel furnishes sufficient alkali to ensure all the free and saline ammonia being driven off in the case of ordinary sewage and effluents." Experiments were made to ascertain the rate at which free and saline ammonia in sewage effluents were evolved with and without the addition of a little sodium carbonate solution:—

Procedure.—One litre of water was put into a series of flasks and to every second flask was added 1 cc. Normal Na_2CO_3.

Solution.—All were boiled till free from ammonia. 25 cc. of the same sewage was added to one pair of flasks (one with, the other without, alkali) and distilled. 100 cc. of each distillate was first collected then a number of 50 cc. fractions.

Owing to the amount of ammonia which came over with fractions 1 and 2, aliquot parts were taken for nesslerisation.

1. Culcheth Homes. Salford Guardians.

Filtered Effluent.

25 c.c.

Fraction.	With Alkali.	Without Alkali.
(1)	100—80·0	100—70·0
	5=4 ·0	5=3 ·5
(2)	50—11·5	50—16·0
(3)	50— 4·5	50— 6·0
(4)	50— 1·5	50— 4·1
(5)	50— 0·0	50— 1·0
	97·5	97·1
	cc. NH_4Cl soln.	cc. NH_4Cl soln.

2. Farnworth U.D.C.

Filtered Effluent.

25 cc.

With Alkali.	Without Alkali.
100—1·0	100—1·2
50=0 ·5	50=0 ·6
50—0·0	50—0·0
50—0·0	50—0·0
50—0·0	50—0·0
50—0·0	50—0·0
1·0	1·2
c.c. NH_4Cl soln.	c.c. NH_4Cl soln.

3. Salford Corporation.

Tanks.

25 cc.

With Alkali.	Without Alkali.
100—60·0	100—50·0
5=3·0	5=2·5
50— 7·4	50—12·5
50— 3·5	50— 4·0
50— 1·2	50— 1·5
50— 0·0	50— 1·2
72·1	69·2

4. Wardle U.D.C. (Higher).

Tanks.

25 cc.

With Alkali.	Without Alkali.
100—128·0	100—98·0
5=6·4	5=4·9
50— 12·0	50—22·0
50— 4·0	50—12·2
50— 1·1	50— 6·5
50— 0·0	50— 2·5
	50— 1·5
	50— 1·0
145·1	143·7

5. Swinton and Pendlebury U.D.C. (Pendlebury) Filtered.

25 cc.

With Alkali.	Without Alkali.
100—94·0	100—76·0
5=4·7	5=3.8
50— 9·0	50—18·0
50— 3·6	50— 8·0
50— 1·1	50— 3·5
50— 0·0	50— 1·0
107·7	106·5

6. Whitefield U.D.C.

Tank Effluent.

25 cc.

With Alkali.	Without Alkali.
100—50·0	100—38·0
5=2·5	5=1·9
50— 3·5	50— 7·5
50— 1·0	50— 5·0
50— 0·0	50— 2·5
50— 0·0	50— 1·1
54·5	54·1

7. Whitefield U.D.C.

Tank Effluent.

25 cc.

With Alkali.	Without Alkali.
100—32·0	100—26·0
5=1·6	5=1·3
50— 3·5	50 6·0
50— 1·2	50— 2·7
50— 0·0	50— 0·8
50— 0·0	50— 0·5
36·7	36·0

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8. Rochdale Corporation

Tanks and filters.

25cc.

With Alkali.	Without Alkali.
100—70·0	100—50·0
5=3·5	5=2·5
50— 7·2	50—10·0
50— 2·0	50— 8·0
50— 0·0	50— 5·5
50— 0·0	50— 3·2
	50— 2·0
	50— 1·0
79·2	78·7

9. Heywood Corporation.

Tanks.

25 cc.

With Alkali.	Without Alkali.
100—90·0	100—74·0
5=4·5	5=3·7
50— 6·8	50—14·0
50— 2·1	50— 6·0
60— 0·4	50— 4·0
50— 0·0	50— 1·5
50— 0·0	50— 0·5
99·3	100·0

These experiments show that the evolution of ammonia when no sodium carbonate is added prior to distillation is slow and that there is an advantage in using a little carbonate of soda.

Dr. McGowan refers, in Appendix 2, to an experiment where he took 100 cc. of sewage, 50 cc. distilled water, and 0·05 grammes of caustic soda and distilled the liquid, but this experiment is not on all fours with the usual practice of determining free and saline ammonia, and in no way proves that it is inadmissible to add carbonate of soda in the proportion which I have used it in the above experiments, viz. 0·053 gramme sodium carbonate to 25 cc. sewage effluent diluted to one litre of water.

3. *Jointing of Samples.*

The mercury "jointing" described on page 11 is unnecessary and inadvisable owing to expansion not being allowed for. I have found the following arrangements to work well for "incubated" samples, and also for the determination of dissolved oxygen. No trace of oxygen is found to diffuse into the bottle, and owing to the elasticity of the water in the bent tube there is no risk of breakage.

Description of Apparatus.

The apparatus consists of a three-necked Wolff's bottle, containing a dilute solution of indigo carmine (2 grams per litre). Into the necks are fitted :—*A*. Small stoppered funnel containing sodium hyposulphite ($NaHSO_2$) solution prepared according to my report dated June 30th, 1903, on Schutzenberger's process. *B*. A delivery tube with pinchcock ; *C*. An inlet tube from the hydrogen generator *D*. The stopper from *A* is fitted with two holes, the second one being an outlet tube for the hydrogen gas as shown in side view, fitted with water seal and glass plug *G*.

The tube from *C* is continued to the hyposulphite bulb so as to retain an atmosphere of hydrogen and to keep a constant pressure all through the apparatus. The details of the construction of the hydrogen generator is clearly shown on sketch. Tube *E* is used for blowing to prevent the zinc chloride solution from lying at the bottom and stopping the access of fresh acid to the zinc rods in tube *F*.

Method of Working Apparatus.

Plug *G* is first removed. This allows the acid to rise in the hydrogen generator and a stream of hydrogen gas passes through the apparatus. After all the air has been expelled the plug is replaced, and the stopcock of the hyposulphite bulb is opened, and the solution of indigo carmine is decolourised with the hyposulphite solution. The blue solution retained in the delivery tube *B* is forced out by opening the pinchcock.

The solution of reduced indigo contained in an atmosphere of hydrogen is now ready for use and remains so for a considerable time without further addition of hyposulphite.

Testing of Samples.

In order to detect the presence of dissolved oxygen in the sample the delivery tube *B* is introduced about half-way into the bottle containing the sample to be tested and the pinchcock pressed, thus allowing a small amount of liquid to enter. If oxygen be present a blue colour is developed, the depth of the blue being some indication of the quantity of oxygen present.

Application of Tests.

In order to test the power of a sewage effluent to rob ærated water of its dissolved oxygen a known volume of the sample is mixed with a definite volume of ærated water (town's supply). The mixture is put into a series of bottles (200 cc.) fitted with S. traps as described by me under "Jointing of Samples," and incubated at 75° Fahr. for definite periods of time.

In order to illustrate the value of this method of testing I append the following table (Table 2) setting forth the results obtained from an examination of a series of sewage effluents, collected in the Mersey and Irwell watershed.

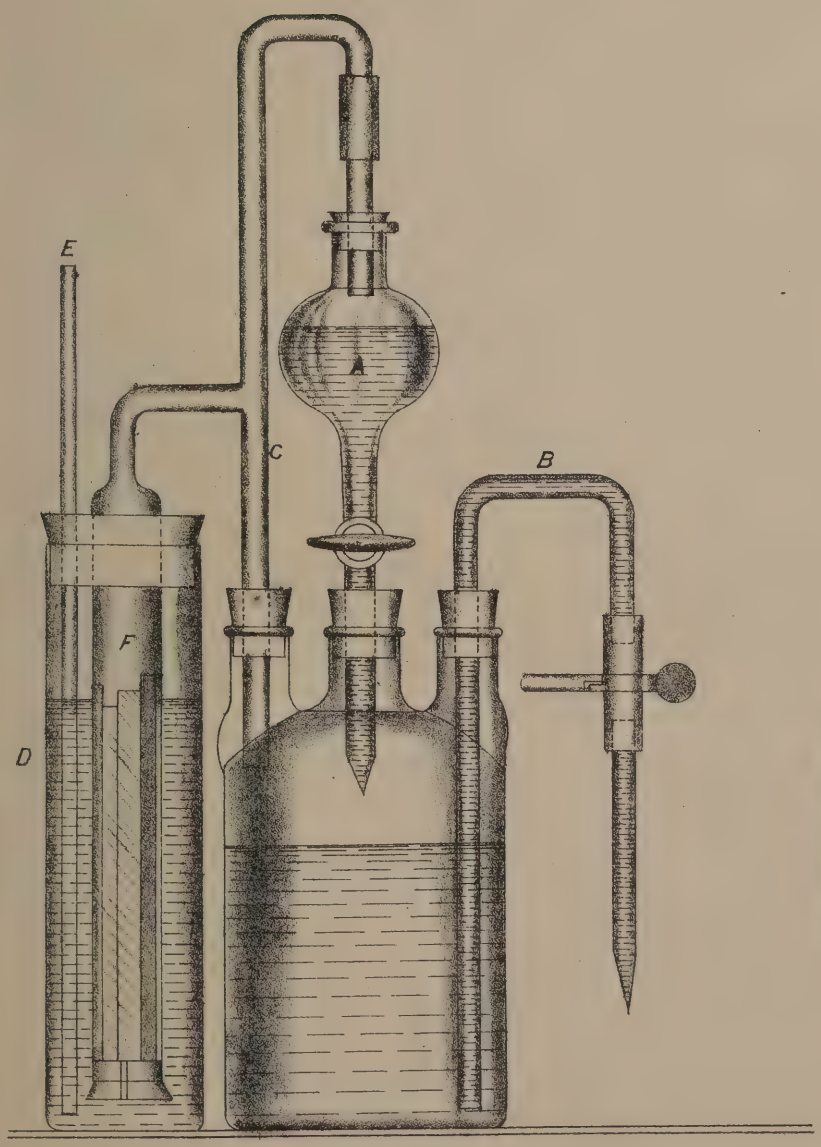
Royal Commission on Sewage Disposal.

APPENDIX TO MR SCUDDER'S EVIDENCE

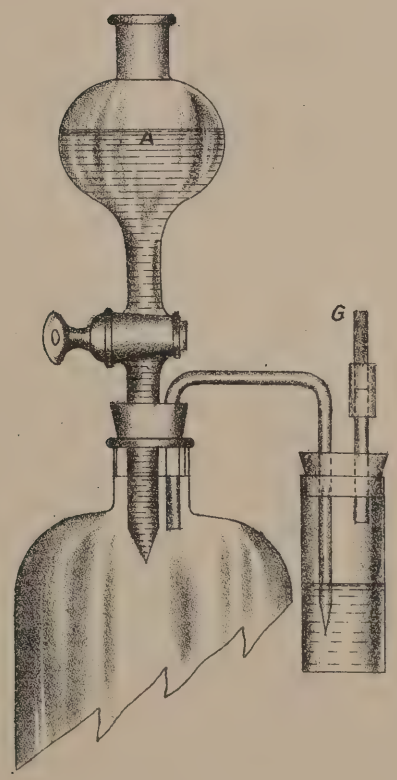
Apparatus for detecting the presence of

DISSOLVED OXYGEN

in Waters and Sewage Effluents.



FRONT VIEW



SIDE VIEW
Shewing outlet tube

SCALE HALF SIZE

FRANK SCUDDER F. I. C.

5238. 05.

Weller & Graham, Ltd Litho. London.

TABLE II.

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TABLE SHOWING OXYGEN ABSORBED 4 HOURS TEST. ALSO DISSOLVED OXYGEN.

(1) One part sewage + nine parts tap water.
(2) Equal parts of sewage and tap water.

No.	Oxygen absorbed 4 hours test.	Dissolved Oxygen.								Grains of Oxygen consumed per gallon of effluent after 48 hours.
		Dilution one in ten.			Grains of Oxygen consumed per gallon of effluent after 48 hours.	Dilution equal parts.				
		At start.	After 1 day.	After 2 days.		At start.	After 1 day.	After 2 days.	After 3 days.	
1	0·15	6·7	6·0	5·9	0·8	6·9	2·3	0·6	0·0	1·26
2	0·15	6·5	6·1	5·6	0·9	7·0	2·5	2·4	0·6	0·92
3	0·17	7·6	6·5	6·1	1·5	7·6	2·6	1·3	1·4	1·26
4	0·18	7·6	6·4	4·3	3·3	7·8	2·1	0·0	0·0	1·56
5	0·22	7·4	7·9	6·2	1·2	7·6	2·5	0·5	0·3	1·42
7	0·30	7·4	5·5	5·5	1·9	6·5	1·9	1·1	0·6	1·08
8	0·33	7·2	6·2	6·1	1·1	6·1	1·5	0·6	0·0	1·10
9	0·37	6·9	6·4	5·6	1·3	7·6	1·6	0·2	0·0	1·48
10	0·37	6·6	6·3	5·7	0·9	7·0	1·9	0·2	0·0	1·36
12	0·40	6·5	5·9	4·9	1·6	7·4	2·1	0·7	0·4	1·34
13	0·44	7·6	6·1	6·1	1·5	6·8	1·6	1·1	1·1	1·14
16	0·47	6·3	5·1	4·4	1·9	6·7	0·0	0·0	0·0	1·34
18	0·52	7·6	6·9	6·6	1·0	7·2	3·0	1·9	1·6	1·06
19	0·55	7·6	5·1	3·6	4·0	7·2	0·0	0·0	0·0	1·44
20	0·56	6·5	5·7	5·3	1·2	5·6	1·3	0·0	0·0	1·12
22	0·61	7·7	7·1	6·1	1·6	7·8	3·6	2·9	2·3	0·98
23	0·64	6·6	6·1	4·7	1·9	4·7	2·6	0·3	0·0	0·88
25	0·66	6·8	6·3	5·9	0·9	7·0	2·6	0·3	0·0	1·34
26	0·72	7·2	6·3	3·8	3·4	6·7	1·8	0·0	0·0	1·34
27	0·77	7·1	5·9	3·9	3·2	4·6	0·0	0·0	0·0	0·92
28	0·97	6·2	3·9	2·2	4·0	4·5	0·0	0·0	0·0	0·90
29	0·99	6·9	5·4	4·4	2·5	4·9	0·0	0·0	0·0	0·98
30	0·99	7·5	5·0	4·1	3·4	4·8	2·0	0·0	0·0	0·96
31	1·07	6·4	3·9	2·4	4·0	3·7	0·0	0·0	0·0	0·74
33	1·21	6·7	5·7	5·3	1·4	6·0	0·2	0·0	0·0	1·20
34	1·28	6·5	3·6	2·0	4·5	4·3	0·9	0·0	0·0	0·86
36	1·42	6·8	3·0	0·0	6·8	8·0	0·0	0·0	0·0	1·60
37	1·53	6·5	4·2	3·8	2·7	5·9	0·0	0·0	0·0	1·18
38	1·73	7·4	5·4	4·3	3·1	6·4	0·0	0·0	0·0	1·28
39	2·04	5·7	0·0	0·0	5·7	3·2	0·0	0·0	0·0	0·64
40	2·27	5·7	0·0	0·0	5·7	1·3	0·0	0·0	0·0	0·26
41	2·38	7·7	2·0	0·0	7·7	7·1	0·0	0·0	0·0	1·42
43	2·66	7·1	0·0	0·0	7·1	3·9	0·0	0·0	0·0	0·78
44	4·91	5·4	0·0	0·0	5·4	0·0	0·0	0·0	0·0	0·00
45	7·48	6·3	0·0	0·0	6·3	4·6	0·0	0·0	0·0	0·92

7 cc. dissolved Oxygen per litre of water is equivalent to 0·7 grain Oxygen per gallon.

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25652. (*Sir William Ramsay.*) I may say that we are much obliged to you for coming to give us evidence for the third time. I fancy most of us have read your evidence and we all acknowledge that the Mersey and Irwell standards have been productive of great good in inducing public bodies in attempting to attend to them. Now, as regards comments, you are aware that strong permanganate was used by Mr. Dibdin?—I was not aware that he used it; of course, I know that he mentioned the use of a strong solution in his book, but I was not aware that he used a strong solution in practice.

25653. Yes, he does.

25654. (*Dr. McGowan.*) He advocates it in his book; at all events, we got it really from there.

25655. (*Sir William Ramsay.*) Another point in connection with your system: when you are dealing with both sewages and tank liquors, which are of very great range of amount of oxygen absorbed, would you not think it advisable to use a solution which will cover both, rather than one which will fall short of either side?—No, I do not, because, after all, the use of permanganate in testing strong sewages is limited in its value.

25656. But is not that a matter of opinion?—Well, it is my opinion.

25657. Of course, you have great experience to back that up?—I have always looked upon the permanganate test in this light; if crude sewage absorbs over 50 per cent. of the five grains of oxygen presented to it in the form of permanganate of potash, the sample is evidently a bad one, and I have never attempted to give a numerical value to a sewage over 2·5 grains oxygen absorbed.

25658. Yes, we were just discussing the question as to whether a strong permanganate gives any value at all in sewage; and you think the result is not worth having?—No; the way I look at it is this: if it is a very strong sewage, you should measure its strength by some other means than permanganate of potash; if it is 2·5 or if it is 10, the inference you draw from those figures is the same—whether it is 2·5 or 10. In other words, I do not attach much value to the oxygen figures above 2·5.

25659. And do you think a strong solution would be likely to estimate the oxygen figure?—If you want to use a strong solution you should carry out a moist combustion process.

25660. Which you do by determining albuminoid ammonia?—Scarcely, it would be better to convert the organic matter into ammonia by taking solid permanganate, and caustic soda:—a moist combustion process, if you want to get a figure of any value for the oxygen consumed. I think that would be a more valuable figure, but for the purpose of classifying the effluents, and for the purpose of getting figures which will show what purification has taken place, I think that a weak permanganate is preferable to a strong.

25661. But, I suppose on the whole you do not attach much value at all to the permanganate test as an absolute test; except as long as you are dealing with the same effluent which will give comparative results it is liable to break down at any point?—All tests are; that is why I say you should have several tests.

25662. Would you not regard the absorption of oxygen from water as a test which does not break down?—No, I should not; I think all these tests individually break down; I think these tables of analyses point to that inference.

25663. Under what circumstances would an oxygen absorption test break down; I mean absorbing free oxygen from water; what may be called the putrefactive test; surely it will fail only if there is a reducing substance present in your effluent, like sulphate of iron or carbolic acid, or some disturbing cause?—Yes.

25664. If there is an antiseptic present or some strong reducing substance?—Yes.

25665. Absorption of oxygen by Thresh's method, or some other comparable method, is a standard test?—I cannot rely upon that alone. You will notice from these results that sometimes a good effluent breaks down on the absorption of dissolved oxygen; is it to be condemned because it has broken down on that, whilst in all other respects it is satisfactory?

25666. I should say it would, because it would putrefy if put into a stream. The ultimate test is whether it will putrefy or not, you would agree?—Yes, I agree.

25667. Is not the dissolved oxygen the determining factor, whether it will or will not putrefy?—But you cannot rely on that alone.

25668. In exceptional circumstances, such as the presence of a reduceable agent, or the presence of some antiseptic, something like phenol, which prevents fermentation taking place?—I grant that would be an obstacle to the test—the presence of those bodies; but with that removed I do not like to rely upon it solely; for this reason, that it does sometimes show a very high figure where the effluent is, I think, in a satisfactory condition, judged by the other tests.

25669. That is, it would not putrefy?—It would not putrefy, although the absorption of oxygen has taken place; it would not putrefy. I think if you studied these tables—on Table II., sample 19—I think you will see it pretty well illustrates the point; sample 19, the oxygen absorbed, four hours' test, ·55; and yet the grains of dissolved oxygen consumed were four grains. Now, there was something peculiar about that sample absorbing four grains. One would not like to condemn that solely on that test.

25670. Is that a case where you have some reducing agent present; some trade effluent like ferrous sulphate?—No, I do not think so.

25671. Was it tested for that?—Oh, yes, there was no ferrous sulphate or other reducing substance present.

25672. Or anything else comparable—chloride of tin?—I could not answer for that. Take another sample No. 7, where the oxygen absorbed is only ·3, and the dissolved oxygen has been removed 1.9.

25673. But as that pretty well agrees with your first example the same criticism would apply; but as a matter of observation they appear to run pretty parallel as far as you can expect such tests to run parallel; I say you are pinning your faith to the permanganate test; I should rather be inclined to pin my faith to the dissolved oxygen test. The permanganate goes wrong only if you have some reducing substance which uses it up?—Some reducing substance.

25674. Some reducing substance?—Your argument is applicable to both tests.

25675. Yes; in the one case you are going directly to what you wish to find out, namely, whether the substance is to putrefy or not; but in the other, you are employing an arbitrary test like the permanganate test, which may be of any strength you like, you will admit, provided it is always used at the same strength?—Yes.

25676. In the one case you gain a certain amount of information which does not bear on the subject and is only auxiliary; it may or it may not bear; and in the other case, oxygen absorption, you have a test which has a bearing on the putrefaction, which after all is the final test to which you wish to subject your effluent?—I hardly follow; I do not agree that such a definite difference can be established between the two tests.

25677. You only know the permanganate test divides organic matter in the effluent into two kinds, one of which is less oxidisable than the other. In the case of the dissolved oxygen, in presence of microbes, you are absolutely estimating the fermentability of the stuff; you let that go to the very end till no more oxygen is absorbed; now that is what you are going to do with your effluent: you are to put it, finally, into some tank, channel, or stream, where it will be under those conditions. If it does not putrefy under those conditions it is a good effluent; if it does putrefy under those conditions it is a bad effluent; and you can test whether it is good or bad on a small scale by mixing it with river or tap water and finding out how much oxygen is absorbed; do you not agree?—I do not agree with you entirely. I do not follow your observations, because, in these experiments which I have made there are effluents which rob water of its dissolved oxygen, and yet which do not putrefy.

25678. Again I must ask you, is it certain that in such cases you have not an antiseptic present; certain organic

compounds in the shape of trade effluents or nitrates present which can be drawn upon in the one case and not in the other ?—As I have pointed out nitrate plays an important part; if you have nitrate present then you only remove any dissolved oxygen slowly.

25679. That is true, but you remove the dissolved oxygen first, and then the nitrate is drawn on ?—They go simultaneously as a rule.

25680. I believe not; we have had a good deal of evidence to show the opposite. The dissolved oxygen goes first and the nitrate follows ?—I put in some figures before you last time I gave evidence rather contradictory of that statement.

25681. I think we have both made our points. I do not think we shall get any further by following this out ?—Yes.

25682. As regards your critique of Dr. M'Gowan's method, that an error of one tenth of a cubic centimetre of the sodium hyposulphite solution in titrating, we generally read ·01 of a centimetre; that would reduce the error to one-tenth ?—Yes, reading to one hundredth of a c.c. is very delicate indeed.

25683. To one hundredth of a c.c., oh, yes; but, admitting that, one-third or one-fourth would be a reasonable error. As regards tingeing the sulphuric acid with permanganate it depends upon how you proceed. The test is merely comparative; if you standardise the permanganate in the same way as you are going to use it, it surely does not matter ?—Well, of course, the sulphuric acid varies in its power to absorb permanganate; the amount of the permanganate consumed varies with the sulphuric acid.

25684. According to the amount of the sulphuric acid you use, but if you use the same under similar circumstances to do the same thing you get the same results; is it not merely a question for the individual analyst to decide for himself ?—Yes.

25685. It is with permanganate as with an indicator; you make the colour you intend and you proceed to colour your unknown substance up to a certain colour ?—Of course it is very slight when you do that; but if you take sulphuric acid and tinge it with permanganate, you will find that the colour gradually fades away, and you have to keep retingeing it.

25686. It goes slowly; I think that is the disadvantage of the process altogether, that you have really no point? —As long as you start with a very faint tinge then I think you involve the minimum error.

25687. We do a blank ?—So do I; always a blank.

25688. I think it is merely a matter of choice; in certain of the instances given in Table II, the oxygen is all exhausted; for example, on No. 4 the oxygen appears to be exhausted ?—Yes.

25689. Again; No. 16, No. 19, No. 20; well, what quantitative conclusion can you arrive at from these results ?—Of course, some of the results have puzzled me. I have done a great deal of work and spent a great deal of time upon them; I have done hundreds of them, but I should say that the time required to remove the oxygen becomes the quantitative factor.

25690. But would not these be cases for more aeration; for giving more oxygen to it, so as to see how much would be absorbed ?—Oh, quite so. In the other column you have the dilution of one in ten; I give more aeration and you have dissolved oxygen present in the liquid at the end of a definite time.

25691. I do not see that any conclusion at all can be drawn from this ?—Dilutions in equal parts.

25692. Yes; only you have not gone to the end; you have exhausted the oxygen, and that is the end of it ?—Yes, that comes to the point whether an effluent should be condemned because it has exhausted its dissolved oxygen when diluted with its own volume of aerated water. My idea was that, instead of having to dilute these effluents, one to ten, I wanted to try if I could not get to a standard dilution, say, equal parts. The first attempt was to try the effluents to see if it was possible to get any effluent that would contain sufficient dissolved oxygen in itself and retain it for 48 hours. That I found was not possible. Then I tried dilution, equal parts. That was why this table (as a typical table) was put before you to show that if one fixed on a definite volume of aerated water to present to the effluent, and if such mixture would retain its dissolved oxygen for three days it would be a good effluent. I started off assuming your former proposition that it was to be the crucial test, and I wanted it to be made so that anybody could use the test, even a layman could use it, or a manager of works, or anybody associated with sewage work, and that was why I included this column in the Table; the experimenter need not know the contents of dissolved oxygen; but if he found dissolved oxygen after incubation at 75 degrees for three days he knew he had got a good effluent; that is really what that column has been put in for. And it also discriminates good effluents from bad ones a little better than the dilution one to ten. If you get down to the bottom of the list from number 27 onwards, the whole of these have lost their dissolved oxygen; so it is a very valuable test for discriminating between good and bad samples.

25693. Then you would regard it as that; as a good test ?—Yes, sir; but it is more difficult when you come to judge between fair and unsatisfactory effluents and to define what the standard ought to be; therefore, upon this dissolved oxygen test, you will find that fixing a standard is a very treacherous and difficult thing to do; that is why I hesitated to accept your statement that it really is the most valuable test without some qualification. The test is quite arbitrary; when I started this work I used a dilution of one in ten, because at that time we had very few good effluents; very few places had got efficient filtration schemes in operation, and we generally tested all effluents coming into the Mersey and Irwell laboratory with a dilution of one to ten. Now, we are getting much better effluents, and I have been trying to come down to what you suggested at our last discussion, to standardise the method of carrying out the dissolved oxygen test; I remember Colonel Harding also pressed me whether effluents could be produced which *per se* contained sufficient dissolved oxygen in themselves and would stand incubation for three days. Well, I think still that is too severe a test, but I am bringing it down to equal parts; I think equal parts would differentiate the quality of effluents; in other words, any purification process that would produce an effluent which, when mixed with its own volume of tap water and was incubated at 75 degrees for three days, still contained oxygen, I should say that was an excellent result, and that is all the value I put upon the test.

25694. And it is a very valuable conclusion ?—Certainly, I would have given you various dilutions; one to two, one to three, one to four, and so on; but this is a representative table, and it shews what I may call certain eccentricities, which is difficult to explain and adds to the difficulty of arriving at a numerical standard.

25695. Still to go on with this permanganate, Dr. McGowan tells me here that if you use strong permanganate the limits will have different values; and as a matter of fact he tells me he finds much greater differences in value between weak permanganate at 65 degrees Fahrenheit and strong permanganate at 80 degrees Fahrenheit than you have at 60 degrees Fahrenheit; roughly speaking the limits are 1 to 1·6, but the ratio is not very regular ?—No, that is so; you see I have given a table there; Table I., the first table, compares a weak solution with a strong solution. Now, as the sewage gets more impure the results tally better; the ratio is better. And then I gave you a diagram which is rather illustrative of the difficulty or the trouble of using a strong permanganate.

25696. As regards the question of weighing the solutions of ammonium chloride, it is a precaution which really does not matter; if the stopper is greased probably it will not leak out; if it is not greased it may ?—The ammonium chloride solutions ?

25697. Yes ?—Yes.

25698. Again, Dr. McGowan tells me that your suggestion as regards the determination of the ammonia correction in the distilled water has not been of much importance. For example, 10 cubic centimètres of the sample (the amount of free ammonia present precluded more), and with a water constant equal to, say, 0·10 cubic centimètres weak ammonium chloride for 50 cubic centimètres distilled water; this gives, for the 200 distillate for albuminoid nitrogen, a correction of

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0·04 parts nitrogen per 100,000; so it might come in?—Personally, I should not like to take one or two cubic centimètres of a sewage; I take not less than 25 cubic centimètres.

25699. Well, in the case of very strong sewage one has to use 5 cubic centimetres or even less; and the distilled water correction has gone as high as 0·2 c.c. of chloride?—I quite agree. I presume only a chemist would take hold of this report to work upon; and the first object ought to be to try to get pure water free from ammonia. My trouble here is that it is introducing complications that ought to be avoided because the chemist ought to start off with pure water. In my laboratory no one is allowed to use water unless it has been tested and found pure.

25700. (*Dr. McGowan.*) How do you purify your water?—First of all I boil it with alkaline permanganate for twenty-four hours.

25701. The whole of the water you use?—The whole of the water we use; then we distil it over and reject the first and last portion of the distillate. The laboratory boy has to attend to this, and we have no water correction to make. I would not allow impure water to be introduced into my laboratory.*

25702. I quite agree that that is the better course, if you can do that?—It is done in most water laboratories. A chemist could of course make a correction. If, however, it is to be used by a man at the works it is far better for him to use the tap water straight away and not allow him to make any correction; what does it amount to? It is nothing of any consequence.

25703. The Grand Junction Water that we have to use in time of storm is very brown and very far from pure?—After all, we have to remember this, supposing you have a free ammonia 1·3, and a free ammonia 1·1—well, what inference can you draw from the difference between those two? they are one and the same, so the little error makes no difference to the inference you have to draw.

25704. The albuminoid?—Well, the albuminoid, take the standard of 0·1, the correction in that will not be above ·005.

25705. It would be more in this water?—More in an exceptional water.

25706. You would have to allow for correction?—Yes, and still I think it is a golden rule with chemists that they try to start with a pure water and with as little correction for impurity as possible.

25707. (*Sir William Ramsay.*) The addition of sodium carbonate is all right; it is quite correct?—I only mention that fact because in our watershed we have induced a certain number of men to follow out this test in the same way as it is followed out in the Mersey and Irwell Joint Committee. Prior to that we had a difference in the results. The difference being due to the varying volume of distillate collected. With a definite amount of sodium carbonate and a definite volume of distillate (250 c.c.s) rapid and accurate results are obtained. In some exceptional cases ammonia is still given off even after 250 c.c. of distillate have been collected. As I told you in my previous evidence that is a very valuable observation to record because it indicates that it is a very bad sewage, and for that reason I rather object to taking such a small amount as one or two cubic centimetres of crude sewage for a determination. I prefer to take 25, no matter what strength the sewage is; and 50 c.c.s is convenient to take for an effluent. When using only 1 c.c. of sewage you are apt to get discordant results, especially in the presence of suspended matter.

25708. (*Dr. McGowan.*) But we do not take 1 cubic centimetre for distillation; we take 10 or 25 and dilute it and take the proportionate amount; we do not actually sample out one or two cubic centimètres?—No, I know that, it is a dilution.

25709. You get a fair sample apart from any large masses of solids?—The albuminoid comes from the solids, and I find the albuminoid results vary tremendously when taking small volumes for the distillation.

25710. (*Sir William Ramsay.*) Have you come to any conclusion as regards the value of the albuminoid ammonia test?—Well, I continue to record the results; I think it has value; as long as you get an effluent below the standard of 0·1 grain per gallon it is a pretty good effluent and not liable to putrefaction.

25711. Yes, but are there no other easier tests; again would you not say that the permanganate test gives you practically the same result; that they run parallel?—Well, they run parallel and yet they do not run parallel. They are comparable between good and bad; but when you come to judge between fair and unsatisfactory, or if you are going to subdivide again, there is where the difficulty comes in; but if you are only going to have two divisions, good and bad, then you get practically the same result.

25712. You may have them different?—Yes, you may have them different.

25713. Are your views as regards standards the same as you gave us some time ago in regard to the standard circular, or have you altered your views at all?—Well, I think the only point that wants modifying is the dissolved oxygen standard. I told you in my previous evidence that I would pass an effluent which did not absorb more than two grains of oxygen per gallon of effluent; that is when it is presented with nine volumes of tap water; I think that is rather too weak a standard.

25714. Would you be inclined to make it more stringent?—I would be rather inclined to make it more stringent. I think it would allow certain effluents to escape which ought not to, and that is why I now prefer to use a dilution of equal volumes.

25715. Then as regards the general question of standards I suppose you agree that it would not be advisable to make hard and fast standards?—No, sir, it would not be advisable.

25716. It depends on the place?—It depends on the place.

25717. I think I asked you before—I may as well repeat the question—do you not agree with the plan of inspection which is adopted under the Alkali Acts, of having inspectors, what may be called a loose standard, such as that of the Mersey and Irwell, to work up to and to try to gradually get the sewage purified up to that standard, but to do it by tact and courtesy rather than pressure?—Yes, I quite agree; we have never gained anything by pressure, but we have gained a great deal by friendly intercourse and friendly help one with another.

25718. You know under the Alkali Act how that is worked out?—Yes, I was trained under the late Dr. Angus Smith, who was the chief inspector under that Act.

25719. That there has been an enormous improvement in the atmosphere?—Yes.

25720. Do you not think that a similar improvement might be effected by the employment of inspectors acting on lines somewhat similar to those adopted by the inspectors under the Alkali Act?—I quite agree you ought to have men of that type and high character to efficiently carry out the work; they must know what they are talking about and what they wish to accomplish, and must show that their advice is appreciated; then you cannot go wrong, and you will get good and lasting work accomplished.

25721. The proposal has been to divide the country into Rivers Boards; and a condition of that would be that each Rivers Board should have its inspector, and that he should be charged not merely with the disposal of the sewage, but also with the water supply of the district. It might need more than one man, of course, in a large district; and that, with a central office either here or somewhere else, is the plan which we are recommending; do you approve of that?—I do approve of that, but I do not quite approve of the way; the way I read your recommendation was that the Conservancy Board should have the power to interfere between the manufacturers and local authorities. I think that would require modification, if it is your intention.

25722. You think that should be reserved for the Central Board.—I think so. Supposing the Mersey and Irwell Joint Committee undertook to settle a dispute between a manufacturer and a sanitary authority, as to whether his effluent was to go into a sewer or not, and the Mersey and Irwell Joint Committee decided that it should not go in, according to your recommendations the manu-

* If ordinary water be distilled after acidification with phosphoric acid, the distillate is invariably free from ammonia.

facturer has an appeal to the central authority. Well, I think that would be rather objectionable, because if he got a reversion of the verdict before the central authority the prestige of the Joint Committee would suffer. I think the Mersey and Irwell Joint Committee should be kept from interfering with any of those kind of questions for settlement.

25723. Local disputes, you mean?—Yes. By all means have the command of any officer or anyone that possesses information that will assist the central authority to decide the issue. Have power to summon him to attend and to give evidence, but he must appear on neutral ground. I think it would be a great mistake if any authority or manufacturer who happened to lose, owing to the decision of a Joint Rivers Board, should have the power to approach the central authority and have the case retried. I think it would simplify matters much better if the central authority undertood the whole thing, something like what the Local Government Board does, in holding inquiries into sewage disposal schemes. It might possibly be that the Rivers authority would have no evidence to present. In that case they would write and say: "We do not know anything about this case, and we cannot give you the information," or they might know a great deal about it, and they might be able to give you valuable evidence, but they must be neutral and give independent evidence. Their attendance at an inquiry must come by request of the central authority. It would be very wrong indeed, I think, to mix up authorties and manufacturers with the Conservancy Boards to settle disputes that could be better dealt with by a central authority.

25724. (*Colonel Harding.*) I do not quite gather, Mr. Scudder, what your objection is to the watershed authority, in the first instance, being appealed to by both parties for a decision?—Well, I do not think it should be placed in that position.

25725. But tell us why. Here are two disputants: here is the local body, a watershed authority with an almost complete knowledge of the local circumstances; what is just your objection to both the manufacturer and the local authority referring, in the first instance, the dispute to the watershed authority, with power of appeal to a central authority?—Well, my objection to it is this, that it is a mistake for a Conservancy Board to interfere between two parties both of whom they have jurisdiction over.

25726. Yes. You told us, but why is it a mistake? Here is a body with large knowledge of the circumstances, a body more or less impartial between the two sets of disputants, if the two disputants are willing, in the first instance, to lay the matter before the rivers authority; what is the objection that you see to that course?—I do not know quite how to express my objection.

25727. You say it is a mistake, but why is it a mistake?—Because I think it would cramp them in the future when they had to deal with the result. Take an example. Suppose the Mersey and Irwell Board had to decide between a sanitary authority and a tanner as to the admittance of tannery effluent into the sewers of the sanitary authority, and the Rivers Board said "Put the trade effluent into the sewers, we think it is the right place." And then they found in course of time that the effluent was unsatisfactory, and the Mersey and Irwell Joint Committee had to take proceedings against the sanitary authority for the extension of the filtration area, and they go to Court and say: "The Mersey and Irwell Joint Committee told us to take this effluent in." The Mersey and Irwell Joint Committee was constituted solely to deal with the pollution of rivers. I think they should be kept to that, because, after all is said and done, what information does a Conservancy Board possess which is not easily got at by a central authority? It is a question of scientific information more than local requirements and local conditions; those can be ascertained simply by the Government Inspector who goes down to view; he hears both sides.

25728. Is the view you express the view of your Board?—I have never discussed it with my Board; I am only expressing my own personal view—the view I take of it myself.

25729. We take that as your view, but it does not seem quite convincing to me. I do not quite see why the authority should not undertake that responsibility at the desire of both sets of disputants. However, you say you think it would be an error for them to undertake it in that case?—If I were the official who had to decide whether a certain manufacturer should go into a sewer I should feel very uncomfortable if I decided he should go into the sewer, and the authority perhaps had subsequently to spend £20,000 to deal efficiently with his effluent, and they informed the Local Government Board it was through the official having advised the entrance of this material into the sewer.

25730. But surely such matters would be taken into consideration by the Conservancy Board in giving their decision?—There is where the difficulty will come in; I see great difficulties arising which will want a great deal of investigation, and I think the central authority could take charge of the whole thing and do it more thoroughly and satisfactorily than a Local Conservancy Board.

25731. The discussion of such a matter in London involves more expense than before a local body?—I should not have any discussion in London. The Local Government Board do now go down and hold an investigation in any town, and the central authority could do the same.

25732. Is not that a more complex and costly proceeding than the local one?—No, I do not think so. The Local Government Board official goes down to a place and holds an inquiry. In the case, say, of the Mersey and Irwell Joint Committee desiring to take proceedings against a manufacturer, the Local Government official arrives and he listens to and takes down the evidence presented by the Rivers Board, and then he turns to the manufacturer and asks: "What have you to say?" and he completes his inquiry into the case. I think it only costs £5 each investigation; less than that, about two guineas. You could not have anything cheaper than that.

25733. Do you not think that the parties would, in most cases, be bound by the decision of the local body?—No, I do not think so.

25734. You think they would almost invariably appeal to the Central Authority?—I am afraid they would. If it were modified to this extent, that if the power of appeal from the Local Rivers Board decision was struck out and that the findings of the Rivers Board should be final less trouble would arise. I mean it is the friction that is created between officialism and manufacturers and sanitary authorities in the watershed that I mostly fear.

25735. On the questions of tests which you have just been discussing with Sir William Ramsay at considerable length, I only want to ask you this: you think it is desirable, do you not, that there should be some general test for effluents recommended by this Commission, in order that the results obtained in different parts of the country may be easily compared?—Yes.

25736. And that would be of great value if the Central Authority were permanently established?—Certainly.

25737. Do you think then that as a general test of the quality of effluents the dissolved oxygen test could not be adopted as the best?—Personally I think it is one of the best, but I would not rely solely upon it.

25738. Well, obviously, if for instance you have equal dilution and the whole of the oxygen is absorbed, if you want to know the amount of impurity shown beyond what is shown by the test, in that case you must either introduce more dilutions or you must have additional tests, must you not?—Yes.

25739. But with equal parts of dilution, if you do not absorb the whole of the dissolved oxygen, that test alone will probably be sufficient as indicating the quantity of matter in the effluent?—Yes, it is from a practical point of view, but then you have to look at it from a scientific point of view as well; that is the reason I gave this column of equal dilutions. Going amongst sanitary authorities they used to say: "What will satisfy you?" and we were not able to say definitely what would satisfy us now we are in a position, I think, to say what will satisfy us.

25740. Would you be satisfied in the case of equal dilutions if there was shown to be dissolved oxygen in the mixture after three days?—Personally I would give an undertaking to the man that I would not prosecute him; he would not hear me say anything against him if he could maintain an effluent of that character.

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25741. On the other hand, if in an effluent only half the dissolved oxygen had been absorbed after three days, would you express satisfaction ?—Oh, certainly, if there is any dissolved oxygen at the end of three days with equal dilutions.

25742. Then you would simply express approval so far as to say you do not prosecute ?—Yes.

25743. But if 50 per cent. were left you would go further and express distinct satisfaction, would you ?—Oh, certainly.

25744. Would not such test on the whole be a very simple one and be able to be carried out by workmen, persons at sewage works ?—Yes, and I have brought a little apparatus here to show you how it can be done and carried about. I am inducing sewage managers and ordinary workmen to try and make use of it.

25745. That is the machine you have brought with you ?—I have it in the other room and some samples to test and show how it works.

25746. As you have long been the chemical adviser of the important supervising authority in Lancashire, Mr. Scudder, I should like to take the advantage of your being present before us to-day to ask you one or two general questions on methods of sewage disposal. You have in Lancashire a great number of communities, large and small planted together on the banks of the stream ?—Yes.

25747. And those communities have begun to realise that they have the responsibility, not only of dealing with their dry weather flow but of a certain number of dilutions of their sewage ?—Yes.

25748. In view of the circumstances mentioned, do you think it practicable for many or most of these communities to treat their sewage entirely by land process ?—By land process ?

25749. Yes ?—Oh, no; oh, no, not by land processes.

25750. Because probably areas are not available ?—The area is not available, and land of a suitable kind cannot be obtained.

25751. Then, failing land, is your large experience such as enables you to say that the purification of sewage may be satisfactorily carried out upon areas specially prepared, such as are generally referred to as artificial filters ?—Yes, sir.

25752. You find, for instance, that if a septic tank effluent is dealt with by double contact you get satisfactory results in many cases ?—You do by double contact.

25753. If there was triple and quadruple contact, probably the results would be greatly better ?—Yes.

25754. Do you think, in short, that any desired result of purification may be obtained if the question of financial practicability be ruled out ?—Oh, undoubtedly that has been well established in our watershed.

25755. You are quite satisfied that by what are known as artificial methods the purification, any degree of purification required, may be obtained ?—Yes.

25756. Then do you think that within reasonable limits of cost results good enough may be obtained by artificial filtration ?—Undoubtedly.

25757. And those remarks apply probably to both systems of filtration, either contact or percolating ?—I prefer percolating.

25758. I was going to ask you whether from your large experience in Lancashire you have been able to form an opinion which is better than the other ?—I think percolating filters are infinitely superior to any other system.

25759. Can you briefly tell us why ?—Because they produce a fully oxidised effluent rich in nitrates and a contact system will not give such a highly oxidised effluent.

25760. And probably the effluent from percolating filters contains much more dissolved oxygen ?—Well, the effluent will maintain more dissolved oxygen, and in that respect is superior.

25761. But they are better aërated ?—They are better aërated certainly.

25762. Do you find that with a cubic yard of percolating material you can get a larger volume through than with a cubic yard used as a contact filter ?—Yes; a 60 feet diameter filter, 9 feet deep, percolating will deal with 100,000 gallons of tank effluent per day. I think that works out a little over 350 gallons to the square yard.

25763. Square yard or cube yard ?—To the square yard.

25764. What depth ?—Nine feet deep.

25765. Nine feet deep ?—Nine feet deep.

25766. That would be a little over 100,000 ?—100,000 gallons, a 60 feet filter will deal with. That I have had personal experience with. I have determined that figure. The Local Government Board allow 80,000 gallons for a 60 feet filter; that is if you put a scheme before the Local Government Board, it has to be of sufficient area to deal with 80,000 gallons; as a matter of fact, it will deal with 100,000 gallons, but I do not recommend more than 100,000 gallons to be placed upon a 60 feet filter.

25767. How is the question of percolating filtration affected by the quantity of suspended matter in the liquor going upon the filter ?—Of course, in a percolating filter you make it of coarse material; it is preferred because of the suspended matter being washed out with the effluent, and it is necessary to have subsidence tanks or some form of filtration for the effluent from the percolating filters, rapid filtration; I prefer sand filtration; at present I have only induced the authorities to put down tanks for simple subsidence.

25768. Then two methods are possible in percolating filtration; one that you should first of all very throroughly settle the suspended matter, and put upon the filter what is in effect a well classified effluent, in which case no further process is required afterwards ?—Oh, yes. If you put on a clarified sewage you will lessen the subsequent settlement required, because with, say a settled effluent or a precipitated effluent (there is not much to choose between the two), you practically remove the suspended matter to within three or four grains.

25769. Let me put it this way: suppose you put on a percolating filter an effluent which would only contain four parts per 100,000 of suspended matter, do you foresee that it would be necessary to have, after the percolating filtration a further process, say, such as you have suggested of sand filtration ?—Yes, undoubtedly.

25770. Even then ?—Yes. I have got several cases where we are experimenting now. I induced the local authorities to put down a shallow sand filtration in preference to sedimentation tanks.

25771. Let me have your opinion a little more fully on that, Mr. Scudder. The assumption is you put on four parts per 100,000 suspended matter on your filter ?—Yes

25772. How much would you expect to come out ?—Seven or eight grains.

25773. You say that you bring out seven or eight ? do you mean as an average or do you mean occasionally; —Yes, the average is seven or eight grains.

25774. Where would the other three parts come from ?—Matters in solution becoming insoluble.

25775. Colloidal matter comes distinctly out in suspension ?—Undoubtedly. In fact, the experience I have gained in working percolating filters leads me to the conclusion that I will not put down a contact bed again. I would not have anything more to do with contact beds from the experience I have gained from working percolating filters, because I never realised that you would get so much sedimentation matter thrown out of solution in an insoluble form. A contact bed after it has been in operation for two or three years gets sensitive in its action. It wants a great deal of care and attention. If it is neglected it soon goes wrong—it gets ineffective. If you get a percolating filter you throw off the suspended matter in a granular form and your difficulties are removed, and the life of the filter continues energetic for an unlimited period.

25776. I gather you think a percolating filter should be so constructed that it may pass out with the effluent suspended matter which has not liquified or changed into gaseous form ?—Yes, sir.

25777. It must therefore not be too fine ?—No, sir, it must not be fine; I do not like them a fine. Of course in a contact bed an experienced man puts a fine material on the top for the purpose of arresting the suspended matter

on the surface of the bed; he scrapes the accumulation away and replaces it periodically like an ordinary sand filter used at a waterworks. If he does not do that and makes the filtering material all of the same size, he finds he has to go down to his drain pipes to clean the material, and the labour then becomes very great.

25778. Then a percolating filter constructed to reject what does not digest is an organism capable of continual life?—Yes, sir, undoubtedly.

25779. Have you met with any cases of fine percolating filters in your district?—No, not large ones put down intentionally to deal with the sewage; experimental ones—we have experimental ones working.

25780. I do not know whether you have any knowledge at all of the sewage works at Hanley in the neighbouring county to yours?—No, I do not. I have not been to Hanley for some years.

25781. But you would look with disfavour on fine percolating filters?—Yes, I should. I should like coarse ones and not fine ones.

25782. Why do you not like too fine filters? Is it because there is a danger of their retaining and not passing out the indigestible suspended matter?—There is that, and moreover you are apt to form a slimy growth in fine material rather than in coarse material.

25783. You would be afraid that a fine percolating filter might retain suspended matter and so choke?—Not only that, but there is also trouble with the slimy growth.

25784. But that growth is a surface growth is it not?—No, it gets well down into the filter, a slimy gelatinous growth and when you get that you have to be very careful even with the percolating filter. But if you have it made of coke from the size of a walnut up to the size of your fist you can work a filter and not get it into that slimy condition, and you get your suspended matter thrown off in a granular condition. When it is in the granular powder condition you know your filter is doing good; when slimy it is not getting sufficient aeration.

25785. We have your opinion that the material should be so coarse as to cause suspended matter to come out?—Yes.

25786. I just want to press you further on the interesting point you raised, that however thoroughly the sewage has been clarified before it goes to the filter you are likely to have considerable quantities of suspended matter coming out?—Undoubtedly.

25787. But is that your experience in all cases?—Yes, sir.

25788. Have you met no cases where thoroughly clarified sewage put upon a percolating filter does bring out an effluent which is fairly free from suspended matter, containing not more than, say, three or four parts per 100,000?—Oh, yes, I have observed that and I have looked into the matter, but they can only do it for a limited time—three weeks or a month—then the suspended matter would come out and run up to fifteen grains; it has to come out sooner or later.

25789. Then your experience leads you to the opinion that a percolating filter will bring out more suspended matter than goes on?—That is the result of purification, viz., the impurity removed from the effluent becomes insoluble.

25790. And by throwing out from solution into suspension you bring about some purification?—Quite so.

25791. Of course there is purification of dissolved matters other than those in a granular form?—Yes, if you take the clearness of a tank effluent going on it may be represented by thirty millimetres depth seen through, and after passing through a percolating filter it may rise to 230 millimetres depth seen through—the effluent will be sparkling. The colloidal matters present and part of the soluble matters have been rendered insoluble and form suspended matter.

25792. Assuming you are right a further process is necessary in any case; antecedent settlement having been carried out does it very much matter whether that settlement has been carried very far on not? If you must have, after percolating filtration, a further process, may you not have only partial settlement of the suspended matter and send on to the filter considerably more suspended matter than it has been hitherto taking?—Well, of course, when you put on to any filter suspended matter, you give it a great deal of work to do, and it is a slow process to destroy solid matter on a filter; it will eventually clog up. I have no confidence in putting on to any form of filter an effluent containing suspended matter.

25793. Then your view is that although a further process is required, however thoroughly clarified the tank liquor may be, nevertheless it is desirable to thoroughly clarify it first?—Yes, sir.

25794. Well, that involves, does it not, a large production of sludge?—Yes.

25795. Which in some cases it is very difficult to get rid of?—Yes. I do not see how you are going to get over the difficulty of sludge production if you are going to get thoroughly oxidised effluents and effluents containing large proportions of nitrates or effluents which will retain the dissolved oxygen.

25796. Then, not withstanding the necessity in all cases, as you think, of a further process beyond percolating filtration, you approve of percolating filtration?—I do, sir.

25797. And in regard to such subsequent process you suggested to us just now that sand filtration was the best final feature?—Yes. I should like to see it tried—shallow sand filtration, filtering at the rate of 1,500 to 2,000 gallons per square yard; it is a rapid process; the suspended matter is in a granular condition.

25798. It merely means the suspended matters coming out of a percolating filter are in a state to be readily settled or readily strained off?—Yes, they are.

25799. Have you any experience of settlement instead of this more or less mechanical straining that you have referred to?—Yes.

25800. Well, what effect has settlement after percolating filtration?—It is very satisfactory, but you must have two or three tanks working for a time with one tank off for cleaning. At Hyde, where I have done much work and experimental investigation, one large settling tank has been built, but experience has proved that this is not sufficient and that an extension is necessary; but with a series of shallow settling tanks good results can be obtained. I found that the solid matter collected was liable to putrefaction, and this is a point which I should like to dwell upon for a moment because it modifies an opinion which I gave in my previous evidence. I find the suspended matter is liable to putrefy, but that when it is in contact with the oxidised effluent containing nitrates its putrefying property is minimised.

25801. It is not in the same condition as the suspended matter in the crude sewage; it is to some extent oxidised though not fully oxidised; is that your view?—Well, it is not oxidised—the suspended matter.

25802. You mean that it is not oxidised at all?—No, I should not call it oxidised material.

25803. That it has not in any way changed?—Oh, it has changed; it is in a different condition, but I would not call it an oxidised body; it is a kind of peat; it has altered physically.

25804. In what way has it altered?—It is more granular, settles more rapidly, and is not slimy. Quite black in appearance, but it is not an oxidised body.

25805. Is it equally liable to putrefy as before percolating filtration?—The suspended matter which comes from a percolating filter is liable to putrefy.

25806. To the same extent as before?—Oh, not to the same extent.

25807. That is the point I want to get at; there is a chemical change in the passage through the filter?—When I was here before and gave evidence I told you that the effluent from a percolating filter did not putrefy, even though it contained suspended matter. I was quite correct at that time because I had only retained it with the effluents containing nitrates, but in practical working you will find it eats up all the nitrates in the liquid and begins to putrefy.

25808. Let me put it this way: is the suspended matter thrown down in the settlement tank, after percolating filtration, liable to give less nuisance in drying than the same suspended matter which has not passed through?—Oh, no, not at all, quite a different thing.

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25809. It is much improved ?—It is much improved, Oh, yes. You could not create a nuisance with that material at all.

25810. So although it is to some extent putrefactive it is much less objectionable ?—Oh, certainly ; and it is a very valuable material as a manure. Of course the ideal method really would be to have with percolating filters an area of land and work the land for crops with the sludge and also the effluent from the percolating filters.

25811. Do you suggest that its manurial value is greater after passing through a percolating filter than it was before ?—Yes, its manurial value is greater, I believe.

25812. Its manurial value. I think you said speaking of the matter settled out from percolating effluents, that it was good for manure : is it better for manure than the suspended matter settled before filtration ?—Undoubtedly.

25813. Why ?—In the first place it does not retain so much water. The great difficulty, of course, in farming with sludge is the amount of moisture that is retained in the soil.

25814. Then this a a new point. You find that the sludge after percolating filtration is denser?—Is denser, and it is in a condition to put in to land for crop growing, being in my opinion more assimilative by plant life.

25815. You mean simply because it contains less moisture ?—No. I have got an analysis of it here, setting forth its constitution.

25816. In what way is it better for manure ?—Well, it is free from all those sticky matters and greasy matters found in ordinary sewage sludge.

25817. It is more granular ?—It is more granular.

25818. That is a physical reason ?—It is owing to its physical condition and to the high amount of available nitrogen that it contains that it would be very valuable for improving the manurial value of land for crop growing.

25819. Have you seen any instance of that sand filtration that you have referred to ?—No, only from my own experiments. I induced a firm to put me down a filter for experimental purposes and I filtered about 70,000 or 80,000 gallons a day for a few months to see how it worked —of course, it was only for removing that suspended matter—and it worked admirably.

25820. The matter deposited on the surface of a fine filter such as you have referred to would soon dry, if the filter were rested, would it not ?—Yes.

25821. The water would drain away from it and it would drain dry and crack on the surface and form into small portions ?—Yes.

25822. Which could probably be raked up into heaps and removed ?—Well, yes, you would not allow more than an inch to accumulate on the surface.

25823. In your experience you think that is practicable ? —I do.

25824. Briefly, your experience since we last saw you is in favour of percolating rather than contact filtration ?—Yes.

25825. And you are satisfied sufficiently good results can be obtained by percolating filtration within reasonable limits of cost ?—Yes, sir.

25826. (*Sir William Ramsay.*) I should merely like to ask a question or two in addition to those Colonel Harding has asked you as regards tank treatment. Have you any particular view as to which is the most easily or cheapest worked, whether sedimentation alone, or sedimentation with chemicals or septic tank ; have you made any observations which would lead you to prefer one to the other ?—Yes, of course I have had a very large experience all over the country with regard to precipitation works, and it varies tremendously ; and I dare say the evidence which you will get will be very conflicting ; because if you go to Glasgow, for instance —now I will take one extreme—you will see small tanks in use and they precipitate with alumino ferric, and they draw the effluent off in twenty minutes as clear as possible. I was very much struck with that place as being one extreme, because I was advising Manchester at the time. There I had very large tanks, precipitating with alumina and doing nothing like what they were doing at Glasgow, and could not obtain anything like so good an effluent in appearance. Each sewage has to be decided on its merits with regard to the chemical treatment it will require. As a rule the use of lime and copperas is the most economical and effective method of chemical treatment.

25827. When you are dealing with chemical precipitation ?—Yes.

25828. Would some sewages be better treated by the septic tank ?—I never had any love for the septic tank treatment. I never saw anything that warranted me in saying I was in favour of septic tank treatment. On the contrary, I am rather against a septic tank treatment.

25829. Would mere sedimentation not give you a clear enough substance to put on a percolating plant ?—On a percolating plant, certainly. In the case of Hyde I tried chemical precipitation with lime and copperas ; we worked that for six months because at that time it was thought that a percolating filter would not deal with chemically treated effluent, it required a septic tank effluent, as a septic tank effluent was more liable to nitrify than a chemically treated effluent. I thought I would test it. For six months I worked a chemical effluent on that filter. I got excellent results. I then gave up the use of chemicals entirely and simply had subsidence and obtained equally good results. If you use a septic tank effluent you invariably find you have a minimum of eight grains of solids in suspension going on to the filter bed and that is disastrous, resulting in the clogging of the filter eventually.

25830. With subsidence you can get less than that ? —With subsidence I can get less than that, about three or four grains per gallon ; and in the majority of places where they have had septic tank treatment you will find they are passing it through the tanks at such a rate that it is no longer septic tank treatment, it is only subsidence, it can only be called subsidence ; they allow the sludge to fill up, and when you have a tank with 4,000 or 5,000 tons of sludge in it, it is a drawback. It is not only taking away capacity, but increasing the suspended matter in the effluent. If you go to any place where they are using septic tank effluent and take the effluent flowing away from the septic tank and add five grains of lime to the gallon, you would be surprised at the precipitation you get. You can imagine what filter beds must suffer from getting that amount of suspended matter on to the beds. I do not like septic tanks ; they give you a great deal of trouble. It was alleged they do away with the expense of chemical precipitation, but then if you get suspended matter in your effluent you have to pay for cleansing your filter beds or renewing them, and possibly at a greater cost, but with percolating beds that is not at all necessary. I have a percolating bed four years old ; it is as good as the day it was built. We tried various experiments varying the rate of flow and the suspended matter comes away in different quantities according to the season of the year and the way they work it, but if the filter is worked regularly and fed with a constant feed good results are obtained. With four to five grains of suspended matter coming away then it works splendidly. In the summer months it is throwing off more, in the winter it stores it. We have been able even to observe this by systematic working.

25831. So all through you advise subsidence or chemical precipitation in preference to septic treatment followed by percolating filtration with subsequent settlement filtration either through tanks or through sand. That sums up what you have been telling us ?—That accurately sums it up.

25832. (*Major-General Carey.*) Without any subsequent treatment on land ?—Without any subsequent treatment on land.

25833. Do you consider that the provision of land for subsequent treatment would be useful in conjunction with artificial filtration ?—I do ; if I had a free hand to design a scheme I should certainly get sufficient land whereby I could utilise that solid matter which comes from the percolating filters and grow crops upon it. We did much good work at Manchester years ago with a little area of land. We showed what could be accomplished on certain land, growing oats, cabbages, and turnips,

and things like that, and we got excellent results with the sewage sludge, and where you can obtain adequate areas of land I think it would be valuable to utilise that material with land.

25834. (*Colonel Harding.*) We are to take it that you think the land is useful, not for the treatment of sewage, but for the treatment of sludge ?—Yes.

25835. (*Major General Carey.*) I did not understand that; I thought you said the effluent, after passing through the percolating filter, could be usefully treated on land to get rid of any sediment remaining in it ?—The first thing I would like to see done would be the utilisation of the sedimentary matter from a percolating bed; it is surprising what a quantity does accumulate. I would like to see it applied to land where land can be obtained. There are places where you could not get land, of course.

25836. And do you consider that all kinds of sewage can be purified by percolating filters or other means of artificial filtration ?—All kinds of sewages, sir. And certain kinds of manufacturing sewage also yield themselves to artificial filtration.

25837. Take the case of a town like Bradford, where there is a large quantity of grease brought down from the manufacturing process, mixed with the sewage, and where it is very difficult to take out the suspended matter before putting it on the filters, do you still think that artificial filtration would purify a sewage of that kind ?—Well, of course they must remove the greasy matter before it goes on to the filter. At present they destroy the grease with sulphuric acid. The effluent from that as a matter of fact has been put on percolating filters and excellent results obtained. I daresay you have had evidence from Mr. Garfield on that point; but of course you could not attempt to put crude sewage on the filter bed; it would soon block it up.

25838. Quite so. Have they tried it long enough at Bradford to prove that filters are not blocked up by the grease from the trade effluents ?—Yes, sir, I believe so

25839. That is entirely by the sulphuric acid treatment ?—Yes, sir. *Mr. Frank Scudder, F.I.C., F.C.S.*

25840. Of course it is a very costly treatment ?—Oh, it is very costly indeed; in fact, it will be interesting to see what they do now they have secured the Esholt estate, whether they propose to put down these percolating filters or not. 16 June 1905.

25841. But knowing that, as they must do, it seems rather strange that they should go to the cost of buying this large estate, the Esholt estate, for land treatment ? Oh, certainly. There is very little of it suitable for land filtration in any case; it will do for a public park some day, perhaps.

25842. (*Sir William Ramsay.*) There is one other point before you go, and that is, would you mind correcting and condensing, or getting some one to do it for you, your work on the oxygen absorbed—the work showing the comparative values of oxygen absorbed—from weak permanganate three minutes and oxygen absorbed from weak permanganate four hours, with the temperatures. You have done an enormous amount of work on the subject; we should very much like to have some sort of summary ?—Yes.

25843. I do not know whether it would give you a great deal of trouble to give us such a summary ?—Oh, I will do it with pleasure, but I do not quite follow what your point is.

25844. The point is this, the comparative values of oxygen absorbed from weak permanganate three minutes, oxygen absorbed in four hours, at any particular temperature which you choose ?—Yes, 60 degrees.

25845. 60 degrees in each case. The point is as regards that and the rate at which the substance will take up oxygen from surrounding water, when you are making comparative tests; would you mind ?—I will do that with pleasure.

25846. I have only again to return the thanks of the Commission to you.

EIGHTY-SECOND DAY.

Wednesday, 1st November, 1905.

CRAIGELLACHIE.

PRESENT.

Sir WILLIAM RAMSAY, K.C.B., F.R.S. (*in the Chair*).

Sir MICHAEL FOSTER, K.C.B., F.R.S., M.P. | Colonel T. W. HARDING, J.P., D.L.

Mr. F. J. WILLIS (*Secretary*).

ALSO PRESENT.

Dr. GEORGE McGOWAN. | Mr. C. C. FRYE.

25847. (*Chairman.*) The object of our coming to Craigellachie was, as you know, that we might confer with representatives of the riparian owners and representatives of the distillers in regard to the investigation which the Commission are, by the Royal Warrant, charged to make, for the purpose of ascertaining what methods of disposing of distillery refuse might properly be adopted. The subject matter of our inquiry is of importance alike to the riparian owners and the distillers, and looking to the magnitude of the interests involved it appeared to the Commission to be desirable that this conference should be held, and that they should have the assistance of both parties in determining the lines of the investigation. The date for the conference was fixed, after consultation with both sides, many weeks ago, but last Saturday the Secretary received a letter from His Grace the Duke of Richmond and Gordon, stating that the riparian owners had decided not to attend. I can only say I am much obliged to you for meeting us here to-day, and I deeply regret that the other side are not present also. I think, Dr. Cowie, that you have got some suggestions to make ?—(*Dr. Cowie.*) Yes, we have.

25848. (*Chairman.*) Possibly it might be well to ask you first what has been done since we met you last ?—(*Dr. Cowie.*) Since you last visited the north considerable progress has been made. At Tamdhu Distillery Mr. Robertson will tell you what has been done. 1 Nov. 1905.

25849. (*Mr. Robertson.*) Since the Commission visited us, we have managed to perfect the plant, and to treat all the burnt ale. We had difficulties before, but we have managed to overcome these, and so far have been successful in our efforts. We have managed to arrange the flues so as to regulate the heat to admit of our drying the syrup with the utmost regularity.

25850. (*Chairman.*) How do you dispose of the heat?—(*Mr. Robertson.*) We use the waste heat from the furnaces underneath the boilers which raise the steam for the evaporators.

25851. (*Chairman.*) What is the effluent ?—We get an effluent which is practically pure water.

25852. (*Chairman.*) The nature of this distillate will be a matter for investigation ?—What we now do is to reduce the pot ale, which contains about 3,000 grains per

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gallon of organic matter, to a minimum of three grains per gallon. Of course there is a smell, but we claim that this is as perfect an effluent as can be desired.

25853. (*Sir Michael Foster.*) How do you dispose of the syrup ?—We run the syrup into trays, and these trays are passed into the flue, and we regulate the heat to something between 400 and 600 degrees. At this temperature, we find that we drive off all the acids.

25854. What is the manurial value of the product ?—We get £5 a ton for it at the distillery.

25855. What does the cost come to in your case ?—To put it as simply as possible, at Tamdhu it costs us about one halfpenny per gallon of whisky distilled. At Rothes the combination of distillers have a plant of exactly the same kind as at Tamdhu, and after going thoroughly into the matter, we thought that the cost in wages of running a larger plant would be about the same.

25856. (*Chairman.*) It is a combination between various distillers ?—Yes, between four of us.

25857. The four distilleries are very close together ?—Yes.

25858. So that in your view, you have solved the question, at all events so far as nuisance is concerned ?—Yes, that is what we are doing. I may say, however, that at the general request we undertook to build a chimney at Rothes, two hundred feet in height. This in itself was a very serious addition to the cost of the work.

25859. Does the halfpenny per gallon include the interest on the capital ?—Yes, we reckon that just covers everything.

25860. The process is working well and you do not find any trouble at all ?—No.

25861. (*Sir Michael Foster.*) Do you think that this large expenditure on the works at Rothes will pay you ?—We will not really be able to tell till the end of next season, when the plant will have had a chance of running through a season. I think, too, we might get a better price for our manure.

25862. (*Chairman.*) Do you happen to know that it is worth more than £5 a ton ?—I have some papers here showing analyses by Mr. Tatlock, which I hand in.* He says it is worth really £6 a ton.

25863. Do you use the manure at present ?—We do not use it for anything. We sell all we can make to the manure trade through a broker.

25864. Does it keep quite well ?—Yes ; by application of heat, as mentioned before, we drive off all the deliquescent matters, so that the result is that the manure will keep for years.

25865. (*Colonel Harding.*) This expenditure of one halfpenny per gallon, I take it, is an expenditure which you as a distiller are prepared to continue ?—Yes, in this way that we are always hoping to get better prices.

25866. Then if you don't get better prices than you are doing, you are prepared to incur this expenditure ?—Yes, we can't help ourselves.

25867. I mean it is not an expenditure that is prohibitive ?—At the present time, it is not. At the same time if competition among distillers goes on getting keener, and there is no increase of price for the bye-products, it might come to be a serious matter.

25868. The process at Rothes is the same as at Tamdhu ?—Yes.

25869. What is the proportion of burnt ale that is made ?—We reckon that a distillery of a capacity of 2,000 bushels will have about 30,000 gallons of pot ale.

25870. (*Sir Michael Foster.*) What is done with your steep water ?—We have a continuous flow and filter it upon our waste land.

25871. Is there any objection to that ?—No.

25872. So far as you know, there has been no complaint ?—We do not know of any objections.

25873. (*Colonel Harding.*) In the process of drying the syrup you find that practically no nuisance arises ?—No, there is no nuisance.

25874. (And do you consider the process at Tamdhu is one that is satisfactory ?—I don't think we would spend £12,000 at Rothes, unless it was satisfactory.

25875. You say that the trade is rather bad just now, but supposing that the trade became somewhat worse ?—Then it might be a serious matter for us, but we are always hoping for a better price for the manure.

25876. (*Sir Michael Foster.*) Have you plenty of land at your distilleries ?—We have at Tamdhu, but not at Rothes.

25877. At Tamhdu there is ample waste land ?—At Tamdhu, we are in rather a fortunate position. We got the land from Mr. Grant of Elchies.

25878. (*Chairman.*) What was the arrangement in regard to the land ?—We got it on a twenty-one years' lease.

25879. At a reasonable price ?—Yes.

25880. I am glad to hear that this is progressing so well.

25881. (*Colonel Harding.*) In your case what heat do you have for the dryers ?—We have a supplementary furnace for the dryers which we can use when running the distillery up to its capacity. The waste heat employed is the heat from the furnaces underneath the boilers in which we raise steam for the vacuum evaporators. This waste heat does not come from the working of the distillery at all, and is quite an independent plant.

25882. There are favourable circumstances at Tamdhu but if the distillery was situated higher in the hill the cost to you would be more ?—(*Mr. Robertson.*) Yes.

25883. (*Dr. Cowie*). It comes exactly to this at Tamdhu. They would not require any steam at all there, but would do all the work with water power. In addition to the distillery, now they have an expensive factory in which they burn a large quantity of coals per week, employ a considerable number of men, and have a costly and perishable plant.

25884. (*Chairman.*) You have some other process, Dr. Cowie ?—(*Dr. Cowie*). Yes, at Cardow, Mr. Cummings.

25885. (*Mr. Cumming*). We use the waste heat of the distillery flues for the incineration on brick shelves. We build up the shelves on a system originally started at Longmorn. We pump the pot ale to the top of these, and let it down, regulating the flow into the top shelf, and the flow of the pot ale goes down into a lower shelf, and the flames are coming in the reverse way. I may say that we have supplementary furnaces.

25886. (*Chairman*). Had you any difficulty ?—(Mr. *Cumming*). The only one that suggested any complaint was Mr. Grant of Wester Elchies, when we started it. I think he did this to protect himself in the future, because since that time there has never been a single word. I never even heard it mentioned for the last eighteen months, and the most you can say as to smell is that there is a slight smell of fresh pot ale. We do not really burn it to a cinder. It does not go out in a very dry state. We do not sell the residue as yet. We use it for the land and it is not a marketable commodity as it is in a moist state. My experience is that with, say, one thousand bushels per week, we can consume the whole of the pot ale ; but if we take, say, fifteen hundred bushels, we have a certain residue, and with two thousand bushels, some more residue. We have never found much difficulty owing to the amount of pot ale being carted by the farmers. For the last ten or twenty years, the farmers have taken away a very considerable quantity of pot ale, and we have had no difficulty in getting rid of the surplus.

25887. And as to the other effluents ?—We put them through filtering beds. Last year we put in the yeast from the washings of the backs, and also the spill of the farmers' carts. This caused some trouble in the beds and we found that some of the beds got foul.

25888. You gave it up ?—Yes, we cleaned the beds this year and kept out the yeast and the spill and no pot ale got into the beds. We use some gravel filters along with the clinkers and we found the result is very good.

25889. How did you dispose of it ?—We used the beds as continuous filters, instead of contact beds.

* See Report at end of day's evidence.

25890. (*Sir Michael Foster.*) And the spent lees in the same way ?—Yes, in the same way.

25891. (*Chairman.*) Is it your own farm ?—I lease it. Of course it is a very great matter to have the farm so near.

25892. You find the farmers are taking the pot ale ?—I can say this—that the farmers ten years ago did not use so much as they use now.

25893. (*Sir Michael Foster.*) What is the nature of your land ?—Some of it is cold clay land, and some of it black land on gravel.

25894. It is varied land ?—Yes.

25895. What is the acreage ?—About one hundred and thirty acres.

25896. (*Chairman.*) Do you put it on the pasture ?—Yes.

25897. (*Sir Michael Foster.*) How much pot ale do you put on these one hundred and thirty acres ?—I cannot say how much per acre. We put it on in the winter time. It cannot, of course, be applied all the year round, as, say, when the crops are growing.

25898. How do you put it on the land ?—It is simply thrown from the end of a cart.

25899. You pour it out on the land ?—Yes.

25900. There is no smell ?—It passes away in a moment. In a wet season the pot ale might fail to get down through the land, if there were conditions such as frost which would keep it up. Last year we had rather a light crop, owing to the dry season. I don't see how there would be too much pot ale put on the best land in a good year. In a wet season the crop might go down but, of course, in any good land in a district where there is no pot ale the crop might go down.

25901. (*Chairman.*) I may take it that in your case you have no difficulty with the question ? You are using the pot ale on your farm ?—Yes. Our family have had the farm for 100 years, although, of course, I have it on a nineteen years lease.

25902. (*Sir Michael Foster.*) From Mr. Grant ?—From Mr. Grant, of Elchies.

25903. (*Chairman.*) Is the drainage from the land into the river ?—It is not near the river.

25904. (*Sir Michael Foster.*) Is it high land ?—Some of it is about 200 feet above the river.

25905. (*Chairman.*) That would seem to be a satisfactory method of disposal, if properly conducted.

25906. (*Colonel Harding.*) I see that Mr. Grant, in his evidence, said there was a certain danger in applying burnt ale to the land, as such luxuriant crops would be created : and he went on to say that if you put on much burnt ale, it would burn the pasture. I take it that danger can be counteracted by keeping records of the amount of burnt ale put on and using what is safe for the land ?—That is so. I think Mr. Grant had in his mind at the time the case against the Daluaine Company. They there put on thousands of gallons of pot ale on a small place, and, admittedly, it did damage for the time being.

25907. Do you require supplementary heat in your destructor, in addition to your waste heat ?—Yes.

25908. Have you been able to form an opinion as to the cost incurred at Cardow ?—The cost per gallon would be very small—I should not think half of what Mr. Robertson has said in their case.

25909. Do you suggest that your process is a better process than the process at Tamdhu ?—Yes, for us, but if we were not near a railway station, and could not get coals cheap, and did not have facilities to put the residue on the land, I would say we would have a difficulty. We would then be the better of having a plant which would consume all the pot ale but the cost of the production and the carrying of the coals up the hill would be prohibitive to us now.

25910. So I take it that the waste heat will only evaporate a certain amount of pot ale ?—That is so, after a certain point. I may tell you that Messrs. Gilbey have a plant exactly similar to ours at Knocklands and are able to consume all the pot ale by exactly the same process as we do. The capacity of the distillery is about 1,000 or 1,100 bushels ; and they consume every drop of the pot ale. But I hold that if they went up to a certain figure they could not do so.

25911. (*Sir Michael Foster.*) Could they not enlarge the plant ?—(*Mr. Cumming.*) The distillery was built with a destructor of a certain size, and then there was no question of pollution. But if the distillery was built now, I daresay a plant might be put in which would consume more.

25912. Your plant is not able to take a larger quantity than 1,000 or 1,500 bushels ?—No. I simply say that with regard to the cost per gallon. I can put it like this : that our calculation should be that each ton of coals produces 100 gallons of whisky. Now, with improved methods, and covering our stills with asbestos, we conserve the heat so much as to spare coals, and this would compensate us for the extra coal required for the supplementary furnaces. So that really our coal bill last year was not prohibitive and so far as the coal bill was concerned, we could not consider it out of the way.

25913. What do you do with your other products—your steep water, and so on ?—The steep water we have never had any trouble with. We put it into our dam and dilute it, and it is diluted to such an extent that no injury can arise from it.

25914. (*Chairman.*) You turn the steep water out of the dam ?—We dilute the steep water, and we find that by dilution it does not trouble us. We have never had any trouble. We have gone on doing this for ten or twelve years. We could treat it if necessary, but so long as we have no trouble or complaints, we don't do that. It would be quite simple to put it through our beds. We put the spent lees and all other effluents into our filter beds.

25915. (*Sir Michael Foster.*) The steep water goes into the drains ?—Not directly.

25916. How often do you clean the dam out ?—About once a year, or once every two years.

25917. Is there any growth of vegetation ?—There is no vegetation.

25918. From the pond it goes into the river ?—Yes ; of course, it goes through a stream first and thus it is diluted more.

25919. (*Mr. Robertson.*) There is a Report which we got from Mr. Tatlock about the steep water.

25920. (*Mr. Cumming.*) I can say I arranged with Mr. Grant, of Elchies, regarding this point, and discussed it with him along with his Inspector of Fisheries. So long as we did not create any nuisance he had no objection, and we were able to keep free of that.

25921. (*Sir Michael Foster.*) How long have you had the process in operation ?—Ten years, but the process for keeping out the yeast from the beds, that was put in this year. Occasionally the Inspector certainly has said that he thought the beds were not working so well as he would like, and we promised at the end of the season to make them all right, which we did.

23922. (*Dr. Cowie.*) There is another process which the Commission can see at Daluaine and Convalmore Distilleries. There, there is an iron box introduced into the flues : at the end next to the chimney is an exhaust fan, into this iron box there lead a number of nozzles. The pot ale—either pure or precipitated—is forced through these nozzles under high pressure. At the bottom what is not evaporated is pumped over again through the nozzles, until it is concentrated, and then they dry it.

25923. (*Chairman.*) Then there was another process going on—to make cattle food of it ?—(*Dr. Cowie.*) That is no more being carried out.

25924. Another process was the pure land treatment ?—Colonel Smith Grant, Glenlivet, of G. and J. G. Smith, The Glenlivet Distillery, will speak to the pure land treatment.

25925. Tell us what it is ?—(*Colonel Smith Grant.*) I feed part of the pot ale to the cattle, and some of the farmers round about drive it on to their land and the balance I drive on to my farms. At the Glenlivet Distillery we are at present driving on to the land 20,000 gallons of pot ale per week ; the amount

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per acre would be 2,500 gallons per week, this quantity doing eight acres. The ale is not put on to the same acres every week, unless the weather is favourable. Burnt ale without the sludge would do no harm to any land, whatever quantity you put on it. The sludge bears a small proportion to the burnt ale—in the above quantity about 300 gallons. I consider that 150 acres of land would be quite sufficient to utilise all the pot ale from this or any distillery of the like size, and do no harm to the land, but improve it. In the years 1897 and 1898 upwards of 3,000,000 gallons were put on to two acres of land, the land was then sown out with oats. The first oat crop was too heavy, but it was too long of being cut. The second crop (next year) was oats and was a very good one. Third year it was sown out with grass, which was also a fine crop.

25926. (*Sir Michael Foster.*) That is the pot ale without any treatment ?—Without treatment.

25927. (*Chairman.*) There is no chance of it reaching any stream after filtering through a great deal of land ?—No, none.

25928. Is the land improved by this treatment ?—Very much.

25929. Do you find your crops become too luxurious ?—Perhaps in a wet season they are rather heavy.

25930. How much land do you require for this treatment ?—I farm 700 acres, but find that 150 acres are sufficient.

25931. (*Sir Michael Foster.*) You only take a proportion of the pot ale ?—Yes.

25932. What proportion do you take ?—About three-fourths.

25933. (*Colonel Harding.*) Can you tell us what quantity you put on ?—About 20,000 gallons. If you put it on in very dry weather it might be apt to burn the grass ; but if the weather is not very dry you can put on any quantity.

25934. (*Chairman.*) Can you give us any idea of the land which would be required to take the products of any certain distillery ?—A distillery of about same size as mine would require 150 acres.

25935. You say you take about one-fourth ?—I have about 25,000 gallons and I put nearly 20,000 on the land, about 2,500 gallons per week.

25936. (*Colonel Harding.*) What quantity per acre do you put on ?—(*Chairman.*) How much land is necessary for the disposal of your pot ale ?—(*Colonel Smith Grant.*) I may say that the Glenfarclas people last year put their burnt ale all into one field. I am not sure of the extent of it, but they practically put the whole of the pot ale on this land. I was up there and saw the land and thought they were overdoing it. They, on the other hand, said they were not, and they had a magnificent crop of hay.

25937. (*Sir Michael Foster.*) What kind of land was it ?—It was cold land. I am not sure of the extent of the field.

25938. (*Colonel Harding.*) What quantity of pot ale do you consider permissible if the land is good ?—2,000 to 3,000 gallons per week per acre, but it would vary according to the nature of the soil.

25939. (*Dr. Cowie.*) You can tell them that your farm, Minmore, with the worst land in the district, was one of the latest farms, but now it is one of the earliest and best ?—That is a fact.

25940. (*Dr. Cowie.*) If they want a nice crop of grass they put on pot ale, and in a week or ten days they see the effect

25941. (*Mr. Cumming.*) If you put on pot ale on new grass, hot, it will scorch it, but in six weeks, if wet weather comes on, the grass grows up quite luxuriously. If you put on the pot ale, hot, on a hot day, it will injure the grass, but not permanently.

25942. (*Sir Michael Foster.*) Is it grass land only that you put the pot ale on ?—(*Colonel Smith Grant.*) We put it on the fields before they are ploughed and after ploughing.

25943. (*Chairman.*) Have you any difficulty in getting the pot ale all the year round ?—(*Colonel Smith Grant.*) No.

25944. (*Sir Michael Foster.*) If there is a hard frost, does not that affect you ?—It does not affect us at all. The carts can get over the fields better.

25945. How hot is the pot ale ?—(*Dr. Cowie.*) Probably fifty or sixty degrees Fahrenheit.

25946. ((*Colonel Harding*) In this method of treatment is the cost of distribution met by the improvement in the crops ?—(*Colonel Smith Grant.*) Well, I have the cost of carting, and I employ three or four men to do this.

25947. Is that expenditure met by the improvement on the crops ?—I think so to a great extent.

25948. Can you dispose of the whole ale without cost ?—(*Colonel Smith Grant.*) I would not care to say that. (*Colonel Harding.*) At a small cost ?—Yes, at a small cost.

25949. (*Chairman*). Will farmers not see the advantage of using the pot ale and cart more of it ?—They are doing so.

25950. You don't get any price for it ?—I am glad to get rid of it.

25951. (*Dr. Cowie.*) In connection with this very question, I persuaded a farmer last year to take some sludge to put on part of his land. He put it on part of the worst field on his farm. The result was that this year he had a magnificent crop of turnips better than on any other part of the field. He came to me six weeks or two months ago asking me if I could not put up a pipe to pump the ale up to him, and he would take the whole. Before complying with his request an application was made to the proprietor, but, so far, he has got no reply.

25952. (*Chairman*). I think I am right in saying that there is only another process to be described ?—(*Dr. Cowie.*) We have the bacteriological process at my distillery (Mortlach). We pass it over a limestone bed, and then seven contact beds ; after that we dilute the effluent and pass it over a continuous filter. Since this has been done we have had no trouble.

25953. What do you do with your precipitate ?—We put it into pits, and let it dry, and then the farmers take it away.

25954. Do you think they would pay for it ?—I am afraid they won't.

25955. These are all the processes. Can you tell us how many distilleries are there that are doing nothing in this matter ?—(*Dr. Cowie.*) I am not aware that any distillery in this part of the country is doing nothing. They are all taking some sort of action.

25956. Do some of them simply run the stuff into pits in the ground ?—One or two do that. At Glengiddich, Balvenie and the Dufftown distilleries it is run into pits. At Convalmore they have the evaporation process that you will see to-morrow. At Parkmore they make a syrup of it. This distillery (Craigellachie), was using Russell Duncan's process. They are now driving the pot ale on to the fields. At Aberlour distillery it is precipitated with lime and superphosphates and put over bacteria beds. At Daluaine it is precipitated and the effluents evaporated. At Benrinnes it is blown up a chimney. At Glenlivet the process has been described to you ; and at Cragganmore they put it on to the land. At Balmenach it is treated with precipitate. Coming down the other side of the river the process at Tamdhu, Cardon, Knockando and Macallan, has been fully explained to the Commission. Going further down the river you have heard what is done at Rothes, and this embraces almost all or nearly all distilleries in the district.

25957. So that a large amount of investigation is being done ?—Yes. I think if the proprietors had been here to-day they would have agreed that much of the pollution has been done away with. Of course, the proprietors state to the Commission that nothing has been done. There is also this question of froth. They talked about this, but there must be a certain amount of froth in any soft running stream.

25958. (*Colonel Harding.*) Although at one time there was no unanimity among you on this subject, at the present time every distillery is doing something ?—Quite so.

25959. You are fully prepared to do something ?—Certainly.

25960. What we have had before us to-day goes to show that in certain cases there is a satisfactory result and that the cost is not prohibitive ?—(*Mr. Cumming.*) I would put it in this way. If the proprietors were not satisfied with anything but complete evaporation, that would be a very serious consideration for some distillers. I do not know if certain of the distillers could pledge themselves to adopt any very expensive process as it would perhaps kill them out altogether.

25961. (*Sir Michael Foster.*) It is fairly evident that the comparative costs of the processes may differ in different places, and that it is undesirable to limit distillers to one process if others are efficient and free from nuisance.

25962. (*Chairman.*) I would like to ask you, Dr. Cowie, about the facilities for obtaining land. This is a very important matter.—(*Dr. Cowie.*) It would be a very great advantage to distilleries if we could with some certainty get the land we wanted, because in the meantime it is in the power of proprietors to make the acquisition of land prohibitive.

25963. And with regard to getting the land near the distillery ?—There is a great difficulty about that. We have to get the land near the distillery otherwise the cost would be too serious in bringing the by-products to the land.

25964. (*Sir Michael Foster.*) Is there about the distilleries land which might be got on reasonable terms ? —About a good many.

25965. (*Colonel Harding.*) Is it necessary to lease land for a distillery if it can be shown that the pot ale can be used with advantage upon the land ?—Farmers will take the stuff if it is near them. But if the distillery is down in a valley and the farmers have to cart the stuff, then it is a serious question as they cannot take more than one hundred gallons at one load. Suppose the land is near and the farmers willing to take it, I do not see why the proprietors should object to it being pumped up to them.

25966. (*Mr. Cumming.*) Farmers are getting much more willing to use it. There is one farmer I know who has improved his farm so much that he wants more accommodation for his cattle. I hold that land, in many cases, in the district of Knockando, has been improved to perhaps double its original value.

25967. (*Colonel Harding.*) Seeing that it is advantageous to use the stuff, it is surprising that it should not be encouraged ?—(*Mr. Cumming.*) The landlords do not object to it in a way, but the farmers take a little time to understand it.

25968. Anyway you find that progress has been made, and that they are beginning to appreciate it ?—Yes. They can bring out their cattle now on straw and burnt ale in quite as good condition as on straw and turnips.

25969. (*Sir Michael Foster.*) How do they use the pot ale for feeding ?—When there is a short crop of turnips, and plenty of straw, they use the pot ale largely ; but not so much when there is a full crop of turnips and short straw.

25970. (*Dr. Cowie.*) For the last two years turnips have been usually good, and straw unusually short, but as a rule it is the other way about.

25971. (*Chairman.*) I think that we have heard now all that has been done ; and the question is what we propose to do. Have you anything to suggest, Dr. Cowie ? (*Dr. Cowie.*) Yes. I think we ought to investigate, (1) Whether or not burnt ale improves the land, and does not permanently injure it, as asserted by the riparian proprietors ; (2) The nature of the land most suitable and the quantity that can be applied per acre without injury to the land. (3) To ascertain the cost of treatment by this method. (4) Is it in any way a nuisance ?

25972. If that is to be fully investigated it will be a very long business. I don't think it could be done without great expense.

25973. (*Sir Michael Foster.*) Is there willingness on the part of the Distillers' Association to undertake the expenditure ?—Yes.

25974. It seems to me that the guidance of an agricultural expert is required. I think that you should make experiments as to the application of pot ale to the land, the condition of the crops, the times of application, and so on. There is a large number of problems which might be very profitably worked out by systematic investigation.

25975. (*Dr. Cowie.*) Colonel Grant and Mr. Cumming have facilities ?—(*Colonel Grant.*) I would be very pleased.

25976. (*Dr. Cowie.*) We should like the Commission to supervise and see it, and superintend it in a general way. There is also artificial filtration, (1) To investigate by what method this is best carried out ; and (2) To determine the effects of different effluents on the streams ; (3) To ascertain the cost of treatment by this method ; (4) Is it in any way a nuisance ? Also by evaporation, (1) To ascertain the cost of the plant ; (2) the cost of working and depreciation ; (3) Value of residue ; (4) Condition of the effluent ; (5) Is it in any way a nuisance. Also by incineration. (1) To ascertain the cost of the plant ; (2) Cost of working and depreciation ; (3) Value of residue ; (4) Is it in any way a nuisance. Lastly, to ascertain to what extent purification of distillery effluents should be carried out before it is safe for municipal authorities to take the same into their sewers.

25977. (*Sir Michael Foster.*) Are there many distilleries at which you have water above the distillery without pollution and water below the distillery without pollution, —(*Dr. Cowie.*) Yes. At Cardow there is nothing above the distillery and nothing below it, and at Glenlivet the same condition obtains, and at Glenfarclas and other places. Also you could easily find out some distillery down by the sea and without prejudice to any fishing rights, make any experiments you wanted. With regard to the Duke of Richmond and Gordon's evidence about fish being as plentiful in the lower reaches of the Spey as they were in former years, but not in the upper reaches, it is well known that salmon have a homing instinct, and that if they have been hatched at the mouth of a stream they do not come up.

25978. Have they a hatchery on the Spey ?—(*Dr. Cowie.*) Yes. There is a hatchery down at the sae where thousands of fish are turned out.

25979. If they are hatched low down, they produce their young low down ?—They do not push up the river.

25980. (*Mr. Cumming.*) I know when there was no distillery working on the Spey this autumn that the fishing was practically a failure.

25981. (*Colonel Harding.*) What you mean is that there are other causes besides distillery effluents to account for the presence or absence of salmon ?—(*Mr. Cumming.*) Yes.

25982. (*Sir Michael Foster.*) Can you form any idea of what is the real condition under which fungus grows in the streams and what produces it ?—(*Dr. Cowie.*) There is no doubt, I think, that it is the phosphoric acid in the effluent which causes it. As a matter of observation we find that.

25983. (*Colonel Harding.*) If it has not been tried before, this would be rather an interesting experiment. (*To Dr. Cowie.*) I think that we did not get any opinion as to the cost of the methods of treatment which you have in operation ?—Do you mean to ask what it costs me ? (*Colonel Harding.*) What it costs by treating the pot ale by that process—how much the gallon on the output of whiskey ? (*Dr. Cowie.*) I am afraid I have not got any figures. The cost would be small after the initial expenditure. It would be probably less than one farthing per gallon.

25984. In the meantime you tell us that in your opinion the cost would be relatively small.

25985. (*Chairman.*) What would be the cost ?—(*Dr. Cowie.*) I think the capital expenditure would be about eighteen hundred pounds.

25986. Do you think the Highland and Agricultural Society would undertake the experiment of the land treatment of the pot ale ?—I do not know. Colonel Smith Grant is in touch with the Highland and Agricultural Society. There is a College of Agriculture at Aberdeen, and they perhaps might take it up.

25987. Do you think the College would take it up ? —Well, they are carrying out experiments all over the country, but might I venture to say that any recommendation to them would come more strongly from you than from the distillers.

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25988. And as to the cost of the experiment?—(*Mr. Cumming.*) I think the Distillers' Association would be quite willing to pay the expense.

25989. We have heard about the difficulty in getting land on which to put your pot ale. Is there not any way in which the proprietors could be approached so as to make things easier?—(*Dr. Cowie.*) It is the most economic method, and it is for the benefit of the community that this valuable manure should be utilised.

25990. Can you not impress that upon the proprietors? In many cases it is not purely waste land. It is moor land, and it is not possible to pump the pot ale on to the waste land?—If you put the pot ale on to the waste land, it is surprising how soon the grass will grow on the land. You saw that at Coleburn Distillery, where the waste land there is now fairly good pasture.

25991. It appears to me that the problem would be largely solved if the proprietors would see it in that light, and give you the land at a reasonable rate. It would probably improve their property and go far to solve the whole question. We propose now to visit certain places where we can see the processes which you have described in operation, and we shall then select those which shall be put under observation. We understand that the distillers are willing to give the Commission every assistance in their investigations. We also want to find some distillery which is suitably placed for making observations as to the effect of effluents of known composition on the stream. We have thought it will probably be desirable to make artificial channels of two or three hundred yards length, into such of which could be passed some of the burn water, together with the effluent which is to be tested.

REPORT ON TAMDHU DISTILLERY FERTILIZER BY MESSRS. TATLOCK & THOMPSON, ANALYTICAL AND CONSULTING CHEMISTS, GLASGOW.

HANDED IN BY Mr. ROBERTSON.

City Analyst's and Gas Examiner's Laboratory,
156, Bath Street, Glasgow,
25th November, 1904

Report on a sample of distillery fertilizer, representing this season's make, manufactured at Tamdhu Distillery, drawn on the 15th inst., and received on the 16th inst., from Messrs. The Highland Distilleries Co., Ltd.

An analysis gave:—	Per Cent.
Phosphates	12·28
Potash	4·58
Equal to Sulphate of Potash	8·46
Nitrogen	5·85
Equal to Ammonia	7·10
Moisture	2·20
Phosphates immediately soluble in water	4·60
Phosphates soluble in Wagner's citrate solution	8·29
Potash immediately soluble in water	3·14
Nitrogen immediately soluble in water	·42
Equal to Ammonia	·51
Lime soluble in water	none

These results show that this is a manure of uncommonly high quality in every respect. It is superior to ordinary compound manures in respect that it is not a mere mixture of the ingredients which it contains, but the latter are intimately associated, or combined together, in a way that cannot be attained in the case of a mixture. It is in excellent mechanical condition—that of a fine powder—and remains in this state, suitable for sowing, even after long storage in a damp situation.

It will be seen that 37 per cent. of the total phosphate is immediately soluble in water, and the phosphate thus dissolved is in a much more readily assimilable condition than the soluble phosphates or bi-phosphate of lime which has been rendered soluble by the addition of acids as always otherwise the case. The water-soluble phosphate in this case consists of phosphate of potash, which agriculturists agree is by far the most desirable form in which phosphoric acid can be introduced into the soil or the plant. The reason of this is that phosphate of potash is never rendered insoluble in the soil, as acid-soluble phosphate always is, and the advantage will be obvious. It will be observed that in addition to the phosphate immediately soluble in water, there is a large proportion, amounting to 30 per cent. of the total phosphate, which is citrate-soluble, leaving 33 per cent. of the entire phosphate in a minute state of division, but still superior in form to that which exists in bone meal or guano, and equally available.

With regard to the potash, the analysis shows that practically 70 per cent. of the total is immediately soluble in water, and it is not desirable to have a larger proportion, provided the remainder is entirely available, which it is in this case. It will also be observed that 7 per cent. of the total nitrogen is immediately soluble in water, and in this respect the fertilizer has an advantage over bones, fish manures, meat manures, and dried blood, which do not contain any nitrogen soluble in water. It is almost unnecessary to say that the whole of the nitrogen in the fertilizer is available, the 7 per cent. representing merely what is instantaneously soluble in a limited quantity of water.

As is well known, it is not desirable to have too large a proportion of any ingredient in a manure soluble in water, and this is well shown by the efficient although at first somewhat slow action of bone meal. Soluble salts, employed on account of the nitrogen or potash they contain, should not be used exclusively in any manure, as a considerable proportion of their value is frequently lost by their being washed away before they can be rendered available for plant nourishment.

(Signed.) R. R. TATLOCK & THOMPSON.

EIGHTY-THIRD DAY.

Monday, 22nd January, 1906.

PRESENT.

Sir MICHAEL FOSTER, K.C.B., F.R.S. (*In the Chair*).
Major General CONSTANTINE PHIPPS CAREY, C.B., R.E.
Colonel T. W. HARDING, J.P., D.L.
Sir WILLIAM RAMSAY, K.C.B., F.R.S.
Mr. W. H. POWER, C.B., F.R.S.

Mr. F. J. WILLIS (*Secretary*)

ALSO PRESENT.

Dr. A. C. HOUSTON.
Mr. GEORGE MCGOWAN.
Mr. G. B. KERSHAW.
Mr. C. C. FRYE.
Mr. LITTLEFIELD.

Mr. J. EDWARD WILLCOX, M.Inst.C.E., and Mr. HUGH P. RAIKES, A.M.I.C.E., Civil Engineers, Westminster and Birmingham, called in; and Examined

Mr. J. Edward Willcox, M.Inst.C.E. Mr. Hugh P. Raikes, A.M.I.C.E.

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25992. (*Chairman.*) You are Messrs. J. E. Willcox and Hugh P. Raikes, Members of the Institution of Civil Engineers, and you have had considerable experience of works for the treatment of sewage by artificial means?—Yes (*see also* No. 26144).

25993. I understand that you carried out the works for the treatment of the sewage of the borough of Hanley, and that you would prefer to speak first as to your experience of those works?—Yes (*see also* No. 26144).

25994. Perhaps, then, you would tell us briefly what is the general method adopted at Hanley for the treatment of the sewage?—The old method was precipitation with lime and sulphate of iron, but this is being superseded by the new scheme consisting in liquefying tanks and fine grade percolating filters.

25995. Would you now give us some particulars as regards the conditions at Hanley?—Yes. It will be convenient to set them out under different heads, as follows:

1. Population draining to the works—60,000.

2. *System of Drainage.*—About one quarter of the town is drained on the separate system, but in the remaining three-quarters, the sewers receive the bulk of the surface water.

3. *Infiltration of Subsoil Water.*—The majority of the sewers being laid in dry subsoil, there is very little infiltration of subsoil water.

4. *Water Supply.*—The water supply per head is 25 gallons, which is supplied by the Potteries Water Company from wells in the new red sandstone formation.

Analysis of Water.

Total solids at 112° F.	14·7
Free and saline ammonia	·014
Organic „	Nil
Nitric nitrogen	·28
Combined chlorine	·77
Oxygen absorbed in 4 hours at 80° F.	Nil
Hardness	7·42
„ after heating	4·90

5. *Character of Water.*—The water is moderately soft.

6. *Drainage Area of Borough.*—The whole of the borough, comprising an area of about 1,800 acres, is sewered, and it is nearly all fully built up.

7. *Sanitary Arrangements.*—About 85 per cent. of the population use water closets, and the remainder pails or middens.

8. *Flow of Sewage.*—The flow of sewage to the works is gauged continuously and registered by an automatic recording instrument; the average dry weather flow per 24 hours being about 3,600,000 gallons in summer and about 4,000,000 gallons in winter.

The maximum dry weather flow is usually about 2 p.m. and is at the rate of 4,200,000 gallons per 24 hours in summer.

The minimum dry weather flow is usually about 2 a.m., and is at the rate of 3,400,000 gallons per 24 hours in summer.

The wet weather flow has exceeded a rate of 12,000,000 gallons per 24 hours on thirty-one occasions in twelve months for varying periods up to 3 hours.

25996. Are there any overflows on the sewers and, if so, can you give the maximum and minimum rates of flow in dry weather in the sewers on which the overflows are situated?—This cannot be accurately determined at present, but storm overflows are now being reconstructed.

25997. What is the largest number of gallons of sewage which have reached the works in 24 hours?—14,000,000 gallons.

25998. Can you say what is the volume of water in gallons represented by the average yearly rainfall on the drainage area?—A rainfall of 23 inches over an area of 1,800 acres equals 900 million gallons in one year, but the volume reaching the sewage works depends more upon the rate of rainfall, than upon the total quantity.

25999. Can you give the Commission an approximate statement as to (*a*) the volume of sewage which reaches the works during the year, and (*b*) the volume which passes over the overflows?—This information is not at present available, but is now being collected (*see also* No. 26147).

26000. You have said that there is practically no infiltration of subsoil water?—Yes.

26001. How many gallons of trade effluents enter the sewers daily (twenty-four hours), and what is the nature of these effluents?—About 1,250,000 gallons per day, of mine water heavily charged with iron and 460,000 gallons of waste water from potteries, containing a large quantity of finely divided clay known locally as "slip" in suspension; there are also about 200,000 gallons from paper mills.

26002. Has the Corporation made any rules regarding the reception of trade effluents into the sewers?—No rules are in operation.

26003. Is it found that the trade effluents interfere with the process of purification by reason of their quality, variations in composition, fluctuations of volume or otherwise?—The trade waste does not interfere with the purification of the sewage, but the clay contained in it materially increases the quantity of sludge to be dealt with, and consequently the expense.

26004. What is the average amount of suspended matter in the sewage in dry weather, and what are the highest and lowest figures, in parts per 100,000?—It varies from 55 to 70, the average being about 62.

26005. What is the physical character of these solids?—Average composition is about twenty-nine parts of organic

Mr. J. Edward Willcox, M.Inst.C.E.; Mr. Hugh P. Raikes, A.M.I.C.E.

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solids and thirty-three mineral solids, the organic solids being fairly constant; the variation is due to mineral matter.

26006. Can you give us average analyses of the sewage for the years 1903 and 1904 in summer and in winter?—Yes, the analyses are as follows:—

In Parts per 100,000.

Summer.	1903.	1904.	1905.
Total solids	184·6	182·3	174·7
Chlorine	9·25	9·0	11·3
Free ammonia	2·00	1·85	2·215
Organic ammonia	·712	·765	·998
Oxygen absorbed	3·733	3·650	4·849
Nitric nitrogen	Nil	Nil	Nil
Winter.			
Total solids	191·00	198·10	164·6
Chlorine	7·5	9·60	10·4
Free ammonia	2·03	2·409	2·032
Organic ammonia	·704	·932	·920
Oxygen absorbed	3·971	3·976	5·359
Nitric nitrogen	0·125	Nil	·04

See also No. 26307.

26007. Is it a "strong" sewage, and, if so, what characterises its strength?—The sewage is a little below average strength, the oxygen absorbed in four hours being 4·846 parts per 100,000 (*see also* No. 26148).

26008. Does its strength vary very much from hour to hour, or on different days of the week, and, if so, do these variations affect the quality of the final effluent to a marked degree?—It is very slightly weaker at 6.30 a.m. in organic ammonia, but this does not affect the final effluent.

26009. How do you think "strength" of sewage as affecting purification is best expressed or measured?—By the amount of suspended matter and the oxygen absorbed figure (*see also* No. 26148).

26010. Have you any information as to the bacteriological condition of the sewage in dry weather and in storm times?—No.

26011. Are there any chemical poisons in the sewage?—No chemical poisons are known to exist in the sewage.

26012. Is the sewage always alkaline?—Yes.

26013. Do you find that the amounts of suspended solids are increased or diminished in times of storm; and can you give the Commission the figures at the end of each hour during a storm of some hours' duration?—Yes. The amount is increased by road detritus and accumulations washed out of sewers, but we have no figures as to the quantity at the end of each hour during a storm.

26014. How many years ago were the Hanley sewers laid, and do you know whether they have sunk much in places so as to allow solids to accumulate?—The majority of the sewers have been laid since 1870, but although a considerable proportion are liable to mining subsidence, most of them have such good gradients that this does not cause solids to accumulate except in some of the main intercepting sewers, which are necessarily flatter.

26015. What is the character of the liquid part of the Hanley sewage in storm times?—The dissolved impurities are believed to be reduced approximately in proportion to dilution with storm water, but no analyses are available.

26016. In what way or ways do you think the sewage which comes to the works should be dealt with in storm times? Perhaps I should amplify this question a little. The usual requirements of the Local Government Board are, I understand, that any increase in flow up to three times the normal dry weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters. Do you think these are proper requirements, or do you think they should be modified in any way? It is, I believe, often found that the storm sewage which first comes down to the works contains a largely increased amount of suspended solids, and I should like to know whether you consider that your ordinary (dry weather) plant is exposed to damage in any way—as, *e.g.*, rapid choking—by having to deal with this amount of storm sewage, and whether you think it would be better to adopt some other treatment. Although the storm sewage, including the suspended solids, is a very polluting liquid, possibly the liquid portion alone is not very polluting, and this suggests that settlement of all the sewage arriving at the works in time of storms in tanks for a few hours, after, possibly, the addition of chemicals, might perhaps be a better plan of treatment than passing a portion of it through the ordinary plant, and the balance through storm filters. Would such settlement alone be sufficient for the whole of the sewage arriving at the works in times of storm?—The present requirements of the Local Government Board in regard to the treatment of storm water involve a large amount of unnecessary expense as works designed for treating a volume of sewage equal to three times the dry weather flow are usually quite sufficient to prevent any serious pollution of water courses, and if their capacity is calculated on the basis adopted by the Board they are quite capable of treating a volume up to six times the dry weather flow during storms for short periods when these occur, but as the polluting matter in storm sewage chiefly consists of suspended solids, it would usually be sufficient if these were removed by simple settlement in tanks or rapid straining through fine filters of shallow depth, but even during storms it is inadvisable to increase the ordinary rate of working by more than, say, 100 per cent. in tanks or bacteria beds provided for treating the dry weather flow in order to avoid permanent loss of efficiency which might result from greater irregularity (*see also* Nos. 26148 and 26156).

26017. What shape and size are the storm overflows at Hanley?—Storm overflows are designed to suit the special conditions of each case, but they are usually rectangular in shape and large enough to discharge the whole quantity of sewage coming down the sewer in case this should become accidentally blocked.

26018. Would it be possible to have a standard form of overflow, and how would you fix the point at which overflows should be allowed to come into operation?—It would not be desirable to have a standard form of overflow owing to widely varying conditions, but in most cases overflows might come into operation when the flow exceeds three times the *maximum* dry weather flow which should, if possible, be ascertained by actual gaugings, or the maximum might be taken as double the average in the absence of reliable gaugings (*see also* No. 26160).

26019. Do you think that the point at which storm overflows should come into operation should depend on the configuration of the land, *e.g.*, whether it is hilly or flat, &c., and upon the character of the surface soil geologically?—In determining any rules as to regulation of storm overflows it would not be practicable to take

the configuration or surface geology of the land as the only governing factor (*see also* No. 26163).

26020. Should storm overflows be fixed or moveable ?—Storm overflows should be capable of adjustment in case the volume of sewage received by the sewers should for any reason be materially increased, but when correctly adjusted they should be secured so that no alteration can be made by unauthorised persons (*see also* No. 26168).

26021. Do you think the number of dilutions at which storm sewage may properly be allowed to pass into a stream should be dependent upon the size and nature of the stream ?—Generally speaking, yes; but in the absence of very exceptional circumstances, no untreated storm sewage should overflow from sewers into any water course until the flow in the sewers exceeds a rate equal to three times the maximum dry weather flow (*see also* No. 26295).

26022. What happens to the road water in the part of Hanley which is drained on the separate system ?—About one quarter of the town is drained on the separate system, and road water from this goes straight to stream, but in the remainder the sewers take road water.

26023. Could you give us an analysis of a typical sample of your road water during the early period of a storm ?—The road water has not been analysed, but this could be done.

26024. Have you any information as to the bacteriological condition of the road water ?—No.

26025. Do you consider that in certain circumstances this liquid should be purified ?—Surface water from paved spaces such as markets should certainly be purified, but ordinary street washings may usually be discharged without serious injury direct to natural water courses.

26026. What are your views as to the comparative cost and advantages of the separate and combined systems of sewers ?—The separate system is usually the most costly in initial expenditure but by far the most satisfactory, and the cost of maintenance is usually less where road detritus is excluded from the sewers. Assuming, therefore, that road water need not be treated we should generally favour the separate system (*see also* No. 26303).

26027. Is the Hanley sewage settled, and, if so, how; *i.e.*, by quiescent settlement or continuous settlement; and what length of time does it stay in the tanks or take to pass through, as the case may be ?—At Hanley heavy minerals are removed by continuous settlement in detritus tanks through which the dry weather sewage passes in about 1⅛ hours; but the proper capacity for detritus tanks depends upon the nature of the mineral to be removed and the velocity at which it is deposited. The following are analyses of crude sewage and detritus tank effluent :—

DR. G. REID'S ANALYSES OF CRUDE SEWAGE AND DETRITUS TANK EFFLUENT IN PARTS PER 100,000.

	Crude Sewage.	Detritus Tank Effluent.
Total solids - -	172·9	117·2
Solids in Suspension:		
Organic - -	27·1	7·5
Mineral - -	36·5	12·1
Chlorine - - -	11·3	10·2
Free Ammonia - -	2·259	1·722
Albuminoid Ammonia	0·968	·480
Oxygen absorbed in 4 hours - -	4·846	2·638

See also No. 26309.

26028. Have you data to show what proportion of the suspended matter is settled in half an hour, one, two, three, four, five, six, twelve, and twenty-four hours, if the sewage is given quiescent settlement ?—In the case of Hanley dry weather sewage, two-thirds of the suspended matter is deposited in detritus tanks in one hour, and the quantity deposited is not appreciably increased by keeping the sewage in the tanks for more than three hours.

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26029. What time would be necessary for you to gain a good tank liquor containing, say, no more than six or eight parts of suspended solids per 100,000 from your sewage (without the addition of chemicals), (1) by quiescent settlement, (2) by continuous flow settlement ?—It is seldom possible to obtain this result by any form of settlement alone.

26030. Do you prefer to use settlement tanks in series or in parallel ?—Where slow velocity is required in order to deposit mineral matter sedimentation tanks should be worked in parallel rather than in series.

26031. In the case of continuous flow tanks, do you think there is any advantage in the employment of baffling boards or walls ?—No.

26032. How is the *sludging* of tanks done at the Hanley works, and what is the character of the sludge ? Does any nuisance attend the operation, and, if so, is it serious ? Is there means of storing sludge, or is it necessary to get rid of it as soon as it is removed from the tanks ?—Sludge is discharged from the tanks by gravitation and dealt with in filter presses, without nuisance, no storage being necessary beyond that of the tanks themselves.

26033. Should the heavy (road detritus, &c.) portion of the suspended matter in sewage be removed as a first operation, or do you think it better and more economical to let everything settle in the tanks, and subsequently to screen the sludge ?—Where simple settling tanks are used without chemicals or septic action, the sludge consists chiefly of mineral matter and such tanks are considered only as a preliminary to precipitation or liquefying tanks.

26034. What is the manurial value of sludge, and will farmers take it ?—Sludge has practically no manurial value and farmers will seldom take it.

26035. Are there any chemical poisons in it ?—No.

26036. Do you find any nuisance from the treatment of sewage in settlement tanks ?—No.

26037. Have you had experience as to the chemical precipitation of sewage ?—Yes.

26038. Have you any reason to think that sewage from which the solids have been removed by the aid of chemicals is less easily purified by subsequent filtration than sewage from which the solids have been removed by settlement or by passage through septic tanks ?—This is not a point on which we have made any extended investigation, but our observations rather tend to shew that a chemically treated liquor has a greater tendency to clog the land filters at Hanley (*see* also No. 26312).

26039. Have you tried various chemicals ? Can you give any comparative data on the practical value and cost of different precipitants for the preliminary treatment of sewage, stating whether you are referring to the precipitation of strong or of weak sewage ?—The most appropriate chemical for precipitation must depend on the composition of the sewage; except where this contains a very exceptional proportion of trade waste we think no chemicals are necessary, as we have found that equally good results can be obtained by septic tanks. Septic and precipitation tanks are in use side by side at Hanley and the septic effluent is the best, as it is free from lime, which tends to choke the filters.

26040. What is the most effective way of adding chemicals ?—This depends upon the amount of chemical used, but thorough mixing is essential, either by passing through pumps, mechanical mixers, or other means.

26041. What is the average analysis of the liquor from the Hanley precipitation tanks ? What length of time does the sewage remain in the tanks ?—The sewage remains in the tanks about twenty-four hours and the

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average of tank effluent after precipitation with lime is as follows:—

Dr. Reid's analysis of effluent from Precipitation tank, precipitant Sulphate of Iron and Lime.

Parts per 100,000.		1904.	1905.
Solids	In Solution	87·6	79 0
	In Suspension	2·8	2·3
	Total	90·5	81 3
Chlorine		10·0	9 1
Free Ammonia		2·156	1 656
Albuminoid Ammonia		0·304	0 233
Oxygen absorbed in 4 hours at 80° F.		1·640	0 777

26042. What is the character of the suspended matter in such liquor?—Flocculent organic matter.

26043. Do you find it necessary to add further chemicals to the sludge before it can be dealt with? If so, for what reasons, and what chemicals are used and how are they added?—Yes, additional lime is required in order to counteract glutinous or greasy matter, which would clog the filter cloths in presses, but no additional chemical is necessary where pressing is not in operation. The lime is mixed by compressed air at Hanley, and added just before pressing.

26044. What is the manurial value of the sludge obtained by the chemical precipitation of sewage at Hanley, and will farmers take it?—Sludge has no manurial value beyond that of the lime used for precipitating it, and, even when pressed, it is scarcely worth carriage, so farmers will not take it.

26045. Does it contain any chemical poisons?—No.

26046. Do you find any nuisance from the treatment of sewage in chemical precipitation tanks? Have any complaints been made?—No.

26047. How should septic tanks be shaped?—The best results have been obtained when the capacity equals the dry weather flow and the width is about one-third of length, but these proportions must depend largely on the capacity and the velocity which it is desired to secure.

26048. Should septic tanks be divided into sections?—It is desirable for the total tank capacity to be divided into two or more sections for convenience in emptying and cleaning, and in order to maintain a fairly uniform depth. The maximum capacity should seldom exceed 500,000 gallons. Assuming that the most efficient depth for septic tanks is, say, six feet, the variation from this depth at each end is necessarily greater in very large tanks, owing to fall required on floor for removing sludge by gravitation.

26049. Should septic tanks be used in series or in parallel?—They should be used in parallel in order to secure slow velocity.

26050. Is a scum necessary or desirable?—Scum is not necessary, but sometimes desirable for the purpose of preventing disturbance of the surface by wind.

26051. Should a septic tank be closed in, and, if so, what advantages does a closed tank possess over an open one?—Septic action is not improved by covering in, but the possibility of smell is reduced.

26052. What do you consider the best arrangement for the "feed" and "draw-off"?—The best arrangement for feed and draw-off consists in a weir extending the full width of the tank with scum boards extending say 2 feet below the surface of sewage in front of inlet and outlet.

26053. At what rate is sewage, as a matter of custom, passed through the Hanley septic tanks?—Sewage remains in tanks about twenty-four hours.

26054. What is the most advantageous rate of flow through septic tanks, and what is the rate of flow at which quicker passage through the tanks becomes, in your opinion, distinctly disadvantageous?—Satisfactory results have always been obtained where the capacity of the tanks equals twenty-four hours flow, so that a larger capacity is unnecessary. A smaller capacity is found to increase the suspended matter in effluent.

26055. Is it possible to "over-septicise" a sewage, and, if so, for what reasons, and how is the "over-septicising" brought about?—If sewage is allowed to remain stagnant in a tank it becomes stale or over septicised and is thereby rendered more difficult to purify. Dr. Reid's analyses of filtered effluent at Hanley show that the organic ammonia and oxygen absorbed are increased when the sewage is over septicised.

26056. What is the amount of digestion in your septic tanks, and how do you calculate this? How far do you find that the digestion is affected by the atmospheric temperature?—About half the suspended matter entering the tanks is digested or liquefied while the remainder accumulates, and although the activity of septic action sometimes appears to be temporarily increased by a rise in the temperature, this does not materially affect the composition of the tank effluent. The amount of digestion was calculated when a large septic tank at Hanley was emptied after a year's work by measuring and comparing the volume of sludge it contained with the suspended matter that had passed into the tank as shown by analysis and gaugings of crude sewage and effluent (*see* also Nos. 26169-26314).

26057. Do you think a certain amount of sludge should be removed periodically from septic tanks, or do you prefer to work them for a considerable period without cleaning and then remove all the sludge?—Septic tanks should be emptied and cleaned out when the amount of suspended matter in the effluent exceeds from 5–8 parts per 100,000, though their action should never be interfered with or disturbed when this can be avoided.

26058. How often would you clean out the septic tank?—This depends chiefly upon the amount of mineral or other indestructible matter; but many tanks are not emptied more than once a year.

26059. How do you think the sludge should be taken out of the tank, and how should it be disposed of? Does any nuisance attend the operation?—Sludge may be removed by gravitation, and can be buried or pressed without nuisance.

26060. Do you find that the suspended solids coming away with the tank liquors tend to increase in amount towards the end of the period of working, *i.e.*, as the time approaches for removing sludge from the tank?—Yes.

26061. What amounts of suspended solids, stated in parts per 100,000, are contained in septic tank liquor at the commencement of the period of working the tank, *i.e.*, just after the tank has been cleaned out, and at the end of period, *i.e.*, when the tank is thrown out of use for the purpose of cleaning out, and what is the average amount?—At Hanley we have found that septic tanks do not become efficient for at least three weeks, when the effluent turns black and contains about 5 parts per 100,000 of suspended matter; and this is not appreciably increased after twelve months working.

26062. Should any portion or the whole of the sewage which arrives at the outfall works in storm times be passed through the septic tanks?—The rate of flow through septic tanks should be maintained as uniform as possible, as any material increase during storms is detrimental to the septic action.

26063. If storm sewage is passed through a septic tank does this cause an increase in the amount of suspended solids issuing from the tank?—Yes (*see* also No. 26178).

26064. May you admit storm sewage to your septic tank, to an extent which raises the ordinary level of the liquid, without serious detriment to the functions of the tank?—This has not been tried at Hanley; but if the velocity of flow is maintained uniform by throttling the outlet no harm is likely to result, but additional fall is required for extra depth of tank.

26065. With certain automatic gear the level of the liquid in a septic tank fluctuates. Have you made any observations for the purpose of determining whether such fluctuations disturb the proper working of the tank in any way, as, *e.g.*, by causing an increased amount of suspended solids to issue from the tank?—No.

26066. Do you find that septic tank liquor is more easily treated on filters than settled sewage or than precipitated sewage, assuming that in each case you have the same amount of suspended solids in the tank liquor ?—We have made no actual observations under these conditions.

26067. Are the impurities in solution in sewage materially different from the impurities in solution in septic tank liquor ?—We have made no observations on this point.

26068. Have you any data on the relative value of plain septic tanks and septic tanks filled with rough stones or flints ?—The effective capacity of a septic tank equals the amount of water that it is capable of holding, and this is reduced in proportion to the bulk of any other materials placed in it.

26069. Do you find any nuisance from the treatment of sewage in septic tanks ? Have any complaints been made ?—No.

26070. Do you think it desirable that the suspended solids in sewage should be removed as far as practicable before sewage is filtered ? If so, what do you consider a practicable limit to get down to ?—Yes, suspended solids in tank effluent discharged on to filters should not exceed about 5 parts per 100,000.

26071. How do you consider the removal of suspended solids can best be effected ?—With small detritus tanks followed by liquifying tanks.

26072. Have you any experience of any mechanical device or any special tanks for freeing tank liquor of suspended matter before delivering it to filters ?—Tank effluent is sometimes strained through fine sand in mechanical filters, but it is difficult to deal with the foul washings from these when they are cleaned, and a properly designed tank usually gives good enough effluent without such straining, though the solid flocculent matter is sometimes deposited in distributing carriers or chambers before reaching the filters after its buoyancy has been reduced by the escape of air bubbles.

26073. What other (if any) method of dealing with tank liquor before delivering it to filters do you regard as necessary or desirable ?—Septic tank effluent can be discharged direct on to filters, and although means are sometimes provided for facilitating aeration this does not appear to be necessary or advantageous.

26074. What are your views as to the comparative cost and relative advantages of the various methods of settlement ?—Suspended solids can be more economically and efficiently dealt with by septic tank treatment than by settlement with or without chemicals, settlement without chemicals being inefficient, and settlement with chemicals being more expensive owing to the cost of the chemicals and increased bulk of sludge. Precipitation is sometimes prejudicial to subsequent filtration, for the reason before stated, namely, that actual experience at Hanley shows that the filters become clogged with the excessive amount of lime in the precipitation tank liquor.

26075. As regards contact beds, is it advisable to construct the whole or any part of the interior of building materials, or may you in some cases dispense with this entirely ?—All contact beds should be watertight, and this almost always necessitates masonry walls and floors ; and, in order to facilitate proper drainage and aeration, a smooth concrete floor is practically essential.

26076. Do you find that within certain limits the depth of contact beds may vary without affecting their efficiency ? If so, what limits do you think are permissible ?—Yes, but it is difficult to aerate contact beds more than 3 feet deep, and the cost of constructing them shallower is greater owing to the increased area of floor and length of underdrains required.

26077. What do you consider is the most convenient size for a contact bed ?—Contact beds should not be so large that they take more than one hour to fill during the period of minimum dry weather flow, but in small schemes this can only be secured by the use of a measuring chamber in which the sewage is held up until a sufficient quantity has accumulated to fill one contact bed rapidly.

26078. What do you find to be the best filtering materials ? What is the material (which can be had in practicable quantity) that, while efficient, is in your experience the least disintegrable in a contact bed ?—Crushed saggers from the Potteries possess all the essential qualities of a good filtering material, being hard and proof against disintegration, but it is usually impracticable to use any but local materials owing to the cost of carriage, and either crushed blue bricks, clinker, granite, or flints may be considered satisfactory (*see also* No. 26178).

26079. What size should the filtering material be, and should it be graded in the beds ?—The best results are obtained with material that will pass a $\frac{1}{2}$-inch screen and be retained on a $\frac{1}{4}$-inch (*see also* No. 26182).

26080. How should the bottom of the bed be constructed ?—The bottom of the bed should be constructed of concrete having drains at intervals for carrying off the effluent.

26081. Do you think it generally desirable that sewage should be subjected to some form of tank treatment before it is put on contact beds ?—Yes.

26082. What periods of filling, standing full, emptying, and standing empty do you consider best in practical working for primary beds and secondary beds, respectively ?—Filling not more than one hour, standing full nil, emptying as quickly as possible, standing empty as long as possible, either in primary or secondary beds, very little purification taking place after the oxygen in the bed has been absorbed.

26083. How should contact beds be filled and emptied ?—As rapidly as possible.

26084. What are your views as to automatic gear for filling and emptying contact beds ?—Automatic gear is a good substitute for manual labour on small works, but central control by an intelligent manager is far better, and where gear is used the cycle commonly depends on fluctuations in flow which is detrimental to results, but this is not necessarily the case with all kinds of gear.

26085. What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed per twenty-four hours ?—About half the quantity which could be efficiently purified on percolating filters of corresponding capacity. At Hanley and Manchester 200 gallons per cubic yard per day is too much for contact beds, but a uniformly good effluent has been obtained from percolating filters which have been working for $2\frac{1}{2}$ years at the rate of 400 gallons per cubic yard per day. Quality of tank effluent affects the amount which can be dealt with on contact beds but no analytical figures are available (*see also* No. 26182).

26086. What amount of liquid from a primary bed can in practice be properly treated on each cubic yard of filtering material of a secondary bed in twenty-four hours ?—Degree of purification is roughly in proportion to the rate of working, so the quantity of primary effluent treated on secondary beds must depend upon the amount of purification required. It is found by practical experience that this is so : and contact beds at Hanley are of little use if filled more than two or three times a day even with partially purified sewage.

26087. Can the quantities be increased by more frequent filling and emptying in times of storm, without impairing the efficiency of the beds or the quality of the effluents ?—No ; the quality of effluent will be adversely affected by accelerated working, since this involves a reduction of the period of rest allowed for aeration : but providing the bed is not clogged with solid matter, accelerated working for a short period does not necessarily affect the results afterwards when normal conditions are reverted to.

26088. Is one contact sufficient for the conversion of certain tank liquors into a satisfactory effluent ?—We cannot give any instances where single contact is sufficient to produce a satisfactory effluent.

26089. At what rate or rates do primary and secondary contact beds lose their water-holding capacity ?—This depends upon the quantity of suspended or colloidal matter in the tank liquor and also on the size of the filtering media, as a bed filled with large lumps may not become clogged owing to the solid suspended matters passing through with the effluent. Experimental contact beds at Hanley have been working at the rate of about four fillings per day for two years, but they are now clogged and the effluent has always been very inferior to that produced from percolating filters working at the same rate per cubic yard of media.

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26090. Is the loss of capacity in direct proportion to the volume treated and the amount of suspended solids contained in the liquid which is put into the bed, or to the fineness or coarseness of the material of the bed, or on what does it depend?—Assuming that the filtering media does not disintegrate, any increase in the rate of working must either produce an inferior effluent or else tend to clog the bed with solid matter, though it is impossible to state whether one or the other is in direct proportion to the quantity treated.

26091. Can the material of a clogged bed be washed, and, if so, how can this best be done, and at what cost per cubic yard?—The filtering media can be most conveniently washed by means of a water jet with a good pressure which will flush out the solid matter from a moderately shallow bed, though where fine material is used for the surface this may require removal to a platform where it can be turned over while the jet plays upon it. The cost of removing, washing and returning the material should not exceed 1s. per cubic yard, exclusive of water which may be replaced by filtered effluent (*see also* No. 26319).

26092. How can the capacity of contact beds be best maintained?—By selecting material that will not disintegrate, and working the beds at a uniform rate not exceeding two fillings per day.

26093. What is the average analyses of the single contact and the double contact effluent at Hanley?—No analyses are available, but about half the impurity is usually removed by each contact, so that this is reduced by 75 per cent. with double contact. Percolating filters accomplish far more purification in one operation.

26094. What number of gallons of liquid are treated daily per cubic yard of filtering material in the first bed at Hanley, and what number of gallons are treated daily per cubic yard of filtering material in the two beds?—For the past twelve months, first and second contact beds have been filled four times a day, representing 225 gallons per cubic yard of filtering material in each bed, which equals 112½ gallons per cubic yard calculated on the capacity of the two beds together.

26095. Do you find any chemical poisons in the final effluent?—No.

26096. What is the amount of suspended matter in the primary bed effluent and the secondary bed effluent respectively? Does most of this suspended matter come out in the first flush or not?—Figures are not available; but most of the suspended matter comes out in the first flush.

26097. To what extent does the organic matter of the suspended solids issuing in the effluent from a contact bed differ from the organic matter of the suspended solids going on to that bed?—The chemical composition of suspended solids entering and leaving contact beds is practically the same. This is shown by Dr. Reid's analyses.

26098. Is the first flush of effluent from either set of beds ever putrescible?—The first flush of effluent is always putrescible from the first bed, and frequently from the second also.

26099. Do you find that by increasing the number of fillings in storm times or other times, the amount of suspended solids is increased?—Yes.

26100. May contact beds in times of storm be used as streaming filters, without detriment to their customary efficiency?—Contact beds converted into streaming filters, either temporarily or permanently, give improved effluents providing the sewage is efficiently distributed over the surface.

26101. What was the cost of the contact bed installation at Hanley, and what amount of liquid is treated ordinarily and in storm times?—The experimental contact beds at Hanley cost about £4,500 per acre, and have worked at a uniform rate of four fillings per day with double contact, the depth of each bed being three feet (*see also* No. 26184).

26102. Have you made any experiments which throw light upon the action of contact beds when full and when resting?—The results seem to show that very little purification takes place after air is expelled from contact beds by filling with sewage, most of the purification being accomplished during the process of filling, while the solid matter in the bed is decomposed during the period of rest, when the bed becomes thoroughly aerated.

26103. Have you made a study of the conditions of aeration of contact beds?—When a contact bed is emptied the interstices are charged with air, but no circulation can be observed during the period of rest.

26104. Do you find any nuisance from the treatment of sewage on contact beds? Have any complaints been made?—No.

26105. As regard continuous or percolating filters, what do you find are the best filtering materials, and what size should the material be?—The best material is crushed saggers, this being a waste product in the Staffordshire potteries, and the best size for this material is from a quarter of an inch to half an inch; but almost any hard material that will not disintegrate appears to answer the purpose and good results are being obtained from clinker, granite, gravel, slag, and blue brick, though the best size for different materials varies considerably, the object being to regulate the size of the interstices, rather than the lumps of material itself, so that a mixture of large and small lumps may produce the same effect as a uniformly smaller size. A uniform size is, however, more easily defined and regulated (*see also* No. 26184).

26106. What depth should a percolating bed be to obtain a good effluent?—Excellent results are obtained from septic tanks and filters five feet deep at Hanley, and an analysis of samples of effluent taken at a depth of fourteen inches from the surface show 90 per cent. of purification measured by the reduction of albuminoid ammonia and 89 per cent. by oxygen absorbed. Reduction in parts per 100,000—Albuminoid ammonia, ·5 to ·05; oxygen absorbed, 2·6 to 0·3. The most efficient depth can only be determined by actual experiments in each case (*see also* No. 26184).

26107. Is it generally desirable that sewage should be subjected to some form of tank treatment before it is put on percolating filters?—Yes, preliminary tank treatment is essential with fine grade filters.

26108. Is the material better disposed in the form of two beds, to be fed in succession with the same liquid, or in one deep bed?—Two shallow beds give better results than one deep one having the same capacity, owing to the greater facility for aeration.

26109. How should percolating filters be fed?—By means of a distributor which will secure the uniform application of tank effluent in small doses at regular intervals of time: best results have been obtained where one gallon is discharged on to each super yard of filter 200 times in twenty-four hours, *i.e.*, one dose every seven minutes.

26110. Do you think it best to put on the filter a fairly constant amount of liquid, or do you consider that the amount can be increased in times of storm without impairing the efficiency of the filter or the quality of the effluent?—Increase in rate of working is temporarily detrimental to results.

26111. Is there any practical advantage in artificially heating the liquid which is being treated upon percolating filters?—No.

26112. Have you had any experience to show whether open sides are an advantage to a percolating filter?—Perforated walls may facilitate aeration near outside of bed, but no material advantage is derived from this in the average quality of effluent. The depth of filtering media being much less than the width of filter, there is less resistance to the passage of air vertically downwards with the sewage than to its lateral circulation from the sides, and a strong wind does not affect the quality of effluent where perforated or open jointed walls are used for large filters at Birmingham, Tutbury, Uttoxeter, etc. It is, however, of great importance that the underdrains should be ventilated at both ends.

26113. Have you made any study of the conditions of aeration of percolating filters?—A fresh supply of air is drawn down into the bed of the filter after each dose of sewage is applied (*see also* No. 26234).

26114. What do you consider is the most convenient superficial area for a percolating filter?—The area is only limited by the difficulty of constructing very large travelling distributors which cannot conveniently cover more than half an acre, but in order to provide for fluctuations in rate of flow the total area should be divided into a number of units, except in very small schemes.

26115. Do you think it desirable that the bottom of a percolating filter should be raised from the ground ?—No ; but underdrains should not be waterlogged.

26116. Do percolating filters, in your experience, choke ?—Percolating beds do not choke if properly constructed and properly managed.

26117. Of what nature are the suspended solids in the filter effluent ?—The filtered effluent at Hanley contains no solid matter in suspension.

26118. Have you any experience of, or any suggestions to make on, the settlement or other separation of the suspended solids issuing from a percolating filter ? and to what minimum figure do you think such settlement or other final treatment can be carried as a practical measure ?—If filter effluent contains suspended matter, this should be removed by straining through sand before discharging into any watercourse.

26119. Do you find that the suspended solids in your filter effluent vary much in amount from time to time, and if so, can you explain the causes of such variation ?—No.

26120. What was the cost of the percolating bed installation at Hanley, and how much liquid is treated per acre, per twenty-four hours, at ordinary times and in storm times ?—Percolating beds cost about £5,500 per acre, and about 1,000,000 gallons per day has been constantly and efficiently purified per acre for the past two and a half years at Hanley, the depth of the filter being five feet. The analyses of tank effluent applied to the filters and of filter effluent are as follows:—

	Parts per 100,000.	
	Tank effluent.	Filter effluent.
Solids in Solution	105·3	112·0
Solids in Suspension	4·4	·4
TOTAL	109·7	112·4
Chlorine	8·7	8·5
Free Ammonia	1·820	·081
Organic Ammonia	·270	·029
Oxygen absorbed in 4 hours at 80°F.	1·725	·273
Nitric Nitrogen	·09	1·75

See also No. 26322.

26121. Have you made any experiments which throw light on the action of percolating filters, with regard to the oxidation of the ammoniacal and organic matter in solution, and the organic matter in suspension ?—No.

26122. Have you evidence to show that ammonium salts and organic substances in solution, not of a colloidal nature, pass rapidly through a percolating filter, or that they are first absorbed by the filtering material or by growths on that material, so that their passage through the filter is a very gradual one ?—No.

26123. Have you observed the effects of changes of atmospheric temperature on the working of a percolating filter ?—Atmospheric temperature does not affect the working of percolating beds.

26124. Have you found any trouble from vegetable growths in percolating filters ? If so, have you been able to form any opinion as to the causes of these growths and as to the way in which the growths can be prevented ?—No trouble has been experienced through vegetable growths, but experiments at Hanley show that such growths are more likely to occur on large sized material than with small size, in fact where large and small material were used in two portions of the same filter, the former became quite green while the latter was not affected (*see also* No. 26235).

26125. Do you find any nuisance from the treatment of sewage on percolating filters ? Have any complaints been made ?—No.

26126. What are the relative advantages of percolating filters and contact beds ?—We have never succeeded in obtaining such good results with contact beds, as with percolating filters ; the former are more costly and less efficient.

26127. Do you find that the chance of nuisance is any greater with one form of filter than with another ?—No ; but septic tank effluent will always cause a nuisance if exposed to the air in sprays, and any solid matter accumulating on the surface of the filter produces the same effect.

26128. Have you made any comparative observations which show how many gallons per cubic yard per 24 hours of your tank liquor could be purified on a percolating filter, and how many gallons per cubic yard on contact beds ?—Far better results have been obtained from percolating filters 14 inches deep, than with double contact beds 3 feet deep, when working at the same rate, the composition of tank effluent being the same in each case, namely, that given in answer to question No. 26120.

26129. Could you express an opinion as to how the number of gallons would vary with variations in the strength of the tank liquor ? On what figure or figures would you rely for defining the strength of tank liquor ?—The quantity treated per super yard may to some extent vary with the strength of the tank effluent, but not in direct proportion. There is not merely the actual waterlogging which must be avoided, but the reduction of air space. That is to say, the more water you are putting on a filter the less air can it retain for purification purposes. The strength of tank effluent can best be defined by suspended matter and oxygen absorbed (*see also* No. 26241).

26130. What is your experience of storm water filters ?—Storm water filters which are only used occasionally do little more than remove solid matters in suspension by mechanical straining, and for this purpose a fine shallow bed is better and less costly than a coarse deep one (*see also* No. 26241).

26131. What are practical methods for disposing of sludges, *i.e.*, sewage screenings, material from detritus tanks, and sludge from precipitation tanks, septic tanks, and sedimentation tanks ?—Screenings should be burnt or buried : in the case of inland towns, sludge from any kind of tanks can be conveniently disposed of by running it into channels excavated in the ground, where it can be immediately covered with soil if sufficient space is available, the alternative being to remove the liquid by filter presses so that the comparatively dry cake may be allowed to accumulate without nuisance, or may in some cases be given away as manure.

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26132. Are some methods of disposing of sludge more likely to cause nuisance than others?—The old method of drying sludge on the surface of land is very liable to cause a nuisance, especially during hot weather.

26133. What, in your opinion, constitutes a good effluent?—The filter effluent of which an analysis is given in answer to question No. 26120 is a good one, and no effluent which contains more than ·05 parts and ·27 parts of albuminoid ammonia and oxygen absorbed, respectively, can be considered entirely satisfactory, but a much lower standard is in many cases permissible.

26134. Do you consider that the type of effluent from a contact bed is superior or inferior to the type of effluent from a percolating filter?—We have always obtained better results from percolating filters owing to more efficient aeration.

26135. What test or tests do you chiefly rely upon in judging of the quality of an effluent, and for what reasons?—Oxygen absorbed is the most convenient test, and affords the best guide to the quality of effluent, as it is a direct index of organic impurity.

26136. Is one standard for all effluents passing into non-potable streams possible and desirable, and, if so, what should it be?—Different standards are required for different watersheds, but all might have certain points in common, such as the absence of suspended matter and the amount of oxygen absorbed (*see also* Nos. 26248 and 26306).

26137. What is your experience of the effect of storm water upon filters of various sorts?—Treatment of large volumes of storm water on filters is detrimental to their action, (*a*) temporarily owing to the filter becoming waterlogged, (*b*) permanently by the accumulation of solids and the disturbance of bacterial action.

26138. How far do you consider it advisable for a sewage installation to be worked automatically?—Automatic apparatus can only be considered as an economical substitute for manual labour, intelligent supervision being essential in either case, and the operation of large works should as far as possible be under the personal control of the manager, both as regards rate of working and analysis of effluents, this being secured at Hanley by the arrangement proposed for the Hanley works now in course of construction.

26139. Have you made any systematic observations as to the effect of effluents on streams?—No.

26140. What values do you attach to the different chemical tests in use in connection with sewages and effluents?—The oxygen absorbed test is preferable to any other on account of its simplicity: the practical value of other tests appears to be very uncertain for purposes of comparison.

26141. Are there any further points on which you would wish to speak at this stage?—Since it is found that in order to obtain the best results from bacteria beds, it is of the utmost importance that their operation should be scientifically controlled by a skilled chemist, we have devoted special attention to devising a means whereby the control of the Hanley works should be centralised as far as possible, and should be pleased to submit and explain detail drawings showing the methods to be adopted for—

(*a*) Measuring the total flow of sewage to be dealt with.

(*b*) Recording the rate at which each filter works.

(*c*) For starting and stopping the distributors.

(*d*) Taking samples of filtered effluent for analysis.

The apparatus being so designed that the whole of the above observations and samples may be taken by the managing chemist himself at any time during day or night without leaving the laboratory and without outside assistance, thereby eliminating the possibility of error owing to carelessnesss on the part of subordinates (*see also* No. 26252).

26142. (*Chairman.*) The Commission are much obliged, Mr. Willcox and Mr. Raikes, for the care you have taken in answering the many questions which have been put to you; the questions and the answers have been circulated to all the members of the Commission, so that I think we may take those at once as read?—(*Mr. Willcox.*) Very well, sir.

26143. But I would ask you if you have anything that you would wish now to add, supplementing any question or making any new statement—you can refer to the questions by number; you see we have them all?—Quite so. (*Mr. Raikes.*) We have marked a certain number of the answers, which seem to us to be capable of amplification, on which we might add something, and with your permission we might perhaps go through those in order, if that would be satisfactory.

26144. I think so?—Well, sir, we might say, in regard to question 25992, we have confined our answers very largely to our observations at Hanley, but since our experience relates to a great many other places over the country, there are many of the answers which might need modification when taken generally, and it is for that reason that we should perhaps qualify what we have said in a few particulars. In regard to No. 25993, the wet weather rate of flow has exceeded a rate of 12,000,000 gallons over twenty-four hours on thirty-one occasions. Well, we mention that since it rather shows, that at any rate in the case of Hanley, the necessity for providing for the treatment of such a large volume as six times the dry weather flow is hardly apparent; that is the only reason. And in that case the 12,000,000 gallons represents over three times the dry weather flow, and that was only exceeded on twelve occasions for half an hour, on eleven occasions for one hour, and on eight occasions for periods from one hour to three hours; making thirty-one altogether.

26145. Can you say by how much it was exceeded?—The flow never reached more than 14,000,000 gallons, at which point the storm overflows would come into action, but until that point is reached the storm overflows would not materially affect it. (*Mr. Willcox.*) That was during the year February, 1903, to February, 1904.

26146. (*Colonel Harding.*) Then if not more than three volumes comes to the works at any time, clearly the storm overflows must come into action very early?—(*Mr. Raikes.*) That would be so.

26147. Your observation just now, it seemed to me, that there was no necessity to deal with more than three volumes, because not more than three volumes came to the works, scarcely applies if you allow three more, possibly ten more foul water to pass into the stream through the overflow?—I am afraid I have not made that quite clear; what I meant was that although the overflows are so arranged that as much as four or rather more than four times the dry weather flow can come to the outfall, we find that three times the dry weather flow is only reached on about thirty occasions in the year. It would seem that provision for more than three times is hardly necessary, as it would only be used on these thirty-one occasions. It is quite true that the storm overflows do come into action before six times is reached, but they do not come into action when three times is reached, so that as long as we are dealing with a figure which is below the limit of the storm overflows, the error due to their low fixing does not arise. And then in No. 25999, we have endeavoured to collect data from which we can give the actual number of days in the year when the average dry weather flow was exceeded by different percentages. Well, we very much regret that we have not been able to complete that information, because the measuring arrangements have had to be put out of operation for a short time during constructional work, but we shall be in a position to complete that information very shortly, and if the Commission wish it we could of course afford particulars when they are obtained, as we thought that that would be a reliable statement of what has actually occurred at Hanley.

26148. You will be able then, later on, to give figures?—Yes, we can give those figures. And No. 26007 we are asked, "Is it a 'strong' sewage, and if so, what characterises its strength?" We answer that "The sewage is a little below average strength, the oxygen absorbed in four hours being 4·846." We are aware that the sewage of Hanley is below the average strength, but still it is not so very far below it as to make the results altogether incapable of comparison with other places; in fact, I might mention Longton, Fenton, Leek, Silverdale, Pelsall, and Burslem, as being places within our experience where the sewage is approximately of the same strength; and then on No. 26009 we are asked, "How do you think strength of sewage as affecting

purification is best expressed or measured ?" And we answer, "By the amount of the suspended matter and the oxygen absorbed." That, we are aware, does not altogether agree with the opinions expressed by some other witnesses who have come before your Commission, but we answer if from a purely practical point of view, as being a test which appeals to an engineer; we feel we can deal with it more conveniently in that way in practice, than by a more elaborate chemical test which generally necessitates the consideration of one figure together with another, and it is not so easy perhaps to form a conclusion in that way. At No. 26016 we are asked regarding the requirements of the Local Government Board——

26149. Question 26016 ?—That is so. We do not wish to find fault with those requirements; but it might be worth mentioning as examples of the difficulty we have in persuading local authorities to comply with them, that we have in three specific instances been instructed to forward schemes to the Local Government Board which we know will not comply with their regulations, because those authorities have instructed us that they cannot undertake to fulfil the full requirements, and if the Local Government Board would not consent to the modified proposals that they submit they would no doubt endeavour to procrastinate as much as possible and put the scheme off; in fact, that has already been done in one case for fifteen years, and in the other cases for very long periods, so that if the full requirements are insisted upon it will be found very difficult to carry out any scheme at all.

26150. (*Mr. Power.*) What are you proposing in the particular instance of Hanley in this connection ?—At Hanley the scheme is designed to meet the ordinary requirements of the Board in regard to treating six times the dry weather flow, but there is no land for the filtered effluent.

26151. Six times is the volume of sewage that can be brought down to the works ?—That is so; the works are calculated on that basis for treating a volume of three times the estimated dry weather flow at a certain rate; and again a further volume of three times, making six in all, at an accelerated speed on separate filters. (*Mr. Willcox.*) The Local Government Board have asked the Hanley Corporation to double the area of sewage filters owing to their being no land upon which to discharge the filtered effluent; that means practically an increase of five acres to the Hanley filters, which at £5,500 an acre is a very considerable item.

26152. To deal with the six times the dry weather flow by the complete process, do you mean; has the Board asked them that ?—Yes.

26153. Are you sure ?—Yes. (*Mr. Raikes.*) Our difficulty has rather been that we have not got any recognised standard submitted or stated by the Board at all, but so far as we have understood in our experience as to what they usually require, it is that, in the absence of any land for the final treatment of filtered effluent, the filters for treating three times the dry weather flow shall be doubled; that is to say, if we treat 200 gallons per superficial yard of filters where there is land, we must only treat 100 gallons per superficial yard when there is no land; the increased area of filters treated thus involves an exceedingly heavy expense, and we submit that so far as we have been able to observe that extra expense is a waste of money.

26154. But the balance between the three times the dry weather flow and the six is passed through a different filter to what the first three are at Hanley ?—That is a point we certainly wish to deal with if we might, because we are very much impressed with its importance. The Local Government Board do usually suggest, or at any rate approve, the proposal to provide storm water filters of an entirely different construction, a much cheaper construction, than the ordinary filters. Well, that is a principle which we do not in practice find to be beneficial, because the filters, if they are constructed, I may call it in an inferior way, are less efficient for that reason alone, and also if they are only used occasionally, when a storm happens to occur—possibly in the case of Hanley thirty times a year—we have very little bacterial life, and they act as little more than strainers, so it would seem to show that it would be much better to have spent the money on an increased area of filters of the most efficient construction that could be used all the year round for treating the ordinary sewage, and in fact at Hanley we have a scheme which would enable us to equally divide whatever work there is to do between the whole of the filters that are provided.

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26155. And you would keep the filters in constant use ?—That is our intention, supposing out of six or eight filters, the average number in operation throughout the year would be four; sometimes six or eight would be used; at other times only four or two; but supposing the average number were four, instead of using four particular filters, we would prefer to use them in rotation, so that the whole would have an equal amount of work during the whole year; in that way no filter is over-worked, at the same time no filter suffers from want of work, which is equally detrimental.

26156. The point is, you think you could effect your object with less filtering area than the board has suggested ?—We are quite confident of that, and have done so in several instances. (*Mr. Willcox.*) We should have a larger area of filters dealing with sewage. (*Mr. Raikes.*) That is so; instead of having two acres, of which only half would be in regular use, and the other half only occasionally used, we should prefer to have the two acres always in use; and when a storm occurred we could very easily deal with the extra flow by an accelerated rate of working. We wish to be quite clear about that. At the end of the same answer, No. 26016 that is, we say that "it is inadvisable to increase the ordinary rate of working by more than 100 per cent. in tanks or bacteria beds provided for treating the dry weather flow in order to avoid permanent loss of efficiency which might result from greater irregularity." Of course, the 100 per cent. is a purely arbitrary figure; we must draw the line somewhere, but we mean that if the filters are large enough to treat three times the dry weather flow, say on the Local Government Board's usual basis, of 56 gallons per foot yard, there would be no serious or permanent injury resulting from doubling that rate for a short period during storms, although we are aware that there is a temporary injury from any increased rate. And in regard to that we have made a special experiment which bears out what I have just said, in which we increased the rate of flow through the tanks and filters at Hanley by 50 per cent. for forty-eight hours; and the effect of that was that the suspended matter in the tank effluent was increased from five to seven parts per 100,000 and the albuminoid ammonia in the filter effluent was increased from ·06 to ·095 parts per 100,000; so that in each case there was an increase of nearly 50 per cent., but those results would not be permanently injurious to the filter in our opinion.

26157. It would not be detrimental to the filter ?—Not permanently; it is merely detrimental to the effluent for a short time.

26158. (*Chairman.*) How long did it last ?—That war two days, forty-eight hours; that was merely done with a view to showing that our proposal to deal with storm water by an accelerated rate of working does not seriously affect the filters, although it does slightly injure the effluent. (*Mr. Willcox.*) I think we ought to point out that in the three cases to which we allude the County authorities are supporting the Urban authorities in asking the Local Government Board to accept the reduced area of filters; that is to say that the area should not be doubled because land is not available on which to treat the filtered effluent, and that of course renders it extremely difficult for us.

26159. (*Major General Carey.*) Is it not a new requirement, the area of filter being doubled when there is no land ?—Yes, comparatively new. The fifty-six gallon basis has been taken hitherto, but where no land is available for the treatment of the filtered effluent, the Board now insists on the twenty-eight gallon basis for twice the dry weather flow in the case of separate systems and three times in the case of combined systems. (*Mr. Raikes.*) That requirement has been in operation for two years or more; this is one of three instances—I need not mention the name of the place, but it is a small place—where the expense is a great burden to the ratepayers, and they have successfully put it off for about ten years. We have prepared a scheme which was approved

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by the Local Government Board, involving the treatment of the sewage on filters with treatment on clay land afterwards. After that scheme had been approved it was found impossible to acquire land at a reasonable cost, and for that reason, and also because the land was stiff clay and quite useless, the district council decided to ask the Local Government Board to withdraw that requirement, and they now hear that the Board refuse to withdraw it. The scheme has been delayed three years in consequence of that requirement distinctly and for no other reason whatever, and I mention just as an instance of the difficulty that does arise that this requirement necessitates levelling an acre of stiff clay land which could not possibly be of any use, and which would involve an unnecessary expense.

26160. (*Sir William Ramsay.*) As regards the rainfall; do you think the requirements could be met if taken on the average rainfall in different parts of the country; which varies very much from place to place; in dry places surely it would not be necessary to require storm overflows, whereas in other places it might be extremely necessary?—We have made a note at the end of the evidence with which, perhaps, I might deal later, if that would be convenient to you, on that very point, because it involves a great many considerations, and we should not like to suggest any fixed standard which did not take the local conditions into account. In 26018 we are asked, "Would it be possible to have a standard form of overflow, and how would you fix the point at which overflows should be allowed to come into operation?" And we answer, "It would not be desirable to have a standard form of overflow owing to widely varying conditions, but in most cases overflows might come into operation when the flow exceeds three times the *maximum* dry weather flow which should, if possible, be ascertained by actual gaugings, or the maximum might be taken as about double the estimated average in the absence of reliable gaugings." We say "maximum," because that would to some extent allow for the difference in the conditions applicable to a hilly district and a flat district. It might quite easily happen that in one district a small storm would bring the overflows into action, whereas a larger storm in another district would not affect them at all; so we suggest a maximum, and we do not think it is practicable to have a universal system of overflows or a standard design exactly. The chief difficulty we have found in designing them is that if we restrict the flow of sewage to go to the outfall by any form of orifice or of valve or size of pipe, we can only do so by regulating the head or pressure that may come upon that orifice, and if that is done by an ordinary weir overflow above it, a very sensible error arises on account of the crest depth or the depth above the top of that weir which there is during a storm, and we have prepared a cartoon which we might have an opportunity of showing your Commission, illustrating a method of getting over that difficulty by using a syphon, which has the effect of utilising the head, after the water has fallen over the weir, in the form of suction, so that directly the overflow begins to come into action it has its full discharging capacity available; that we could make clear later.

26161. (*Chairman.*) Have you the cartoon with you?—We have the cartoon with us; Would you prefer to see it later or put it on the table now.

26162. I think we might see it now; if you could hold it vertically I think we could see it better?—You see this is intended to indicate the perspective view of a manhole; it is only for the purpose of explanation, it is not accurate to scale; that is an egg-shaped sewer, and the desired discharge is obtained by an orifice when the water stands at that level.

26163. Which way is the flow?—In this direction, this way (*indicating*), and we have at some point further down the sewer a fixed orifice or penstock which is capable of adjustment to discharge the exact quantity required at the outfall works, and we wish, if possible, to make this overflow discharge the whole surplus without increasing the head on the orifice or penstock, so we cover the top of the sewer with a kind of hood which forms part of the inlet of the syphon, and that is enclosed with a side plate down to that point, and directly the water rises to the level of the syphon or to the level of the overflow weir it runs over the top here and dropping down through this leg of the syphon carries some of the air with it, shown with bubbles here, and escapes at the outlet end, thereby creating a partial vacuum here, and as that relieves the pressure on the surface of this water, the overflow would at once come into action with three or four inches depth of discharge over that weir without any corresponding increase in the height of the water in the sewer itself. Of course, it is quite clear that if the quantity of sewage in excess of the quantity going to the outfall was only small, this overflow would come into action intermittently, running for a minute or two, and then perhaps a large bubble of air would come in and stop it; but it would be quite automatic, and we have no doubt that by using that suction on the syphon system there would be an advantage in overcoming the great difficulty that everybody has found in restricting the head on an orifice. The reason why we should wish to fix the head on the orifice is that the discharge can only be made uniform by that means, because supposing an orifice is calculated to discharge six times the dry weather flow with a head of six inches, if we get nine inches of head the discharge is increased, and this introduces a very large error. In 26019, I do not know that it is necessary for me to read the question and answer——

26164. No, if you give the number of the question?—"In determining the rules as to regulating storm overflows it would not be practicable to take the configuration or surface geology of the land as the only governing factor." Well, it would perhaps be practicable to take it into consideration, but what we mean by that answer is that a standard could not be made proportionate to that alone.

26165–7. Could not be determined by the land?—No; there are many important considerations besides that.

26168. (*Mr. Power.*) Do you not mean that each overflow should be fixed on its own merits?—That is absolutely our opinion, Sir; and in the next question 26020 we say "Storm overflows should be capable of adjustment in case the volume of sewage received by the sewers should for any reason be materially increased, but when correctly adjusted they should be so secured that no alteration can be made by unauthorised persons." The Local Government Board have expressed a very strong preference for an absolutely fixed overflow, and we have consequently been compelled to adopt that system in many cases, but we are of opinion that it is not a convenient system, and really if anyone were determined to evade their requirements by altering the overflow there would be very little more difficulty in doing it if it were fixed than if it were adjustable; it is a fact we can much more readily regulate the discharge to the outfall works by a penstock valve than by the height of a fixed weir alone, because it sometimes means that the weir has only to be sometimes two or three inches above the bottom of the pipe which it governs.

26169. (*Chairman.*) What is your next point?—The next point was, Sir, on question 26056.

26170. The digestion in the septic tank?—That is the one, Sir; we have very carefully tested the amount of digestion that takes place and we find that it is 50 per cent. of the solids brought into the tank at Hanley, but that is less than the experience at some other places, we have cases where tanks have been in operation for several years and have not been cleaned out.

26171. What is the time required for the digestion?—The tanks hold twenty-four hours' flow so that the sewage is in the tanks for twenty-four hours, and we calculated that, assuming the suspended solids remaining in the tanks equal twenty-eight parts per 100,000, that is the actual quantity or 19·6 grains per gallon, that equals 50 per cent. of the solids in the sewage.

26172. (*Mr. Power.*) Was it never subjected to a greater rapidity than one day's flow?—No, except for the purpose of the experiment which I mentioned a little while ago; we did try it then but we think the slightly increased quantity of suspended matter which comes in the effluent when the rate of flow is increased is not very serious; we have not done that in practice hitherto. That is perhaps important, since we say that 50 per cent. of the total of solids are deposited. That seems a large proportion, but it is to a large extent accounted for by the fact that we get a considerable quantity of finely divided clay from the pottery works at Hanley, which is all mineral matter and is therefore all deposited, so that it is perhaps

rather exceptional in that respect and if that finely divided clay or slip, as it is commonly called, were not contained in the sewage we should get a much larger proportion of digestion.

26173 (*Chairman.*) Your digestion of 50 per cent. is with the presence of all that quantity of insoluble mineral matter ?—That is so, Sir.

26174. What is the proportion of that to the total solids have you any idea ?—I am afraid we could not give it accurately; we only know the amount of digestion and the amount of matter that is deposited altogether.

26175. It is very considerable ?—It is very considerable, yes.

26176. (*The Secretary.*) What is the number of the question ?—26056.

26177. (*Chairman.*) The number is not given in the answer to that question ?—No, that was a supplementary note that we thought would be interesting to you. We should hope to have an opportunity of embodying a good deal of those supplementary notes later.

26178. I think the Commission would think it desirable that the witnesses should embody the additions they are making now into the answers when they are finally printed ?—Thank you, Sir. I might say that the answers were of course made to the questions sent to us, and therefore we were to some extent restricted in the answers. And at number 26063 the question is referred to again as to the effect of increasing the rate of flow which I answered in connection with 26016. 26078 is the next one, as to the best kind of filtering media. We find that crushed saggars which are used at Hanley possess all the qualities of a good filtering material, being hard, and proof against disintegration; but it is usually impracticable to use any but local materials owing to the cost of carriage; crushed blue bricks, clinker, or granite may be considered satisfactory. We only mention that particularly because we have been impressed by experience with the fact that the cost of constructing these bacteria beds is far more affected by the price of the filtering media than anything else, though much is often said about the cost of walls or the absence of walls, but that is really immaterial, when perhaps 6d. a yard can be saved in the cost of the filtering media, and carriage is the factor that governs it.

26179. What are saggars ?—They consist of the waste pots that are very roughly formed and used to contain the finer pottery when it is burned, and they are for that purpose put into the furnaces and subjected to a very intense heat, and after they have been used a few times they crack and become useless and a waste product in the district, so that they can be obtained for a small sum, and when crushed and screened they form admirable material for this purpose, but although we have used it extensively in the potteries in Hanley and in Newcastle and other places, the cost of conveying it to other parts of the country might put it at a disadvantage when compared with other material.

26180. What is the usual form of the fragments ?—It is similar to a broken stoneware pipe. (*Mr. Willcox.*) Without the glaze. (*Mr. Raikes.*) It is very irregular in form, but it does not tend to flake off in thin pieces; I think a sample of the material was sent to Dr. McGowan after the visit the Commission paid to Hanley. I dare say he has studied its peculiarities.

26181. Is the surface smooth or rough ?—The surface is rough, very rough, although it is not so hard as to involve great expense in crushing; it is not inclined to disintegrate or break down because we have had filters there in constant operation treating 1,000,000 gallons per day per acre for two and a-half years, and they are now more efficient than ever they have been. (*Mr. Willcox.*) I also ought to say it breaks cubically.

26182. That is the meaning of my question,—cubically ?—Yes. (*Mr. Raikes.*) In question 26079, "What size should the filtering material be, and should it be graded in the beds ?" And we answer, "The best results are obtained with material that will pass a half inch screen,"—and there we were rather endeavouring to suggest a size that would be generally applicable to different kinds of material; but we prefer to alter that and say from half inch to quarter inch for saggars, because it is different for some kinds of material, the object being not so much to fix the size of the material itself as the size of the interstices between the material, and that may frequently be obtained by using a large size and a small size mixed together, it is the size of the interstices we wish to govern, although the practical method of securing that result is generally by fixing the size of the material. And we are also asked whether the material should be graded in the beds; we should always recommend that having determined the best size for any particular material, the bulk of the bed should be made of that size; many beds are constructed of the right size, perhaps for six inches in depth at the top and then it is made much larger below, and the remaining depth appears to be very inefficient. Then 26085—"What amount of tank liquor per cubic yard of filtering material can, in practice, be properly treated in a primary contact bed per twenty-four hours." We have never been able to obtain satisfactory results, or such satisfactory results with contact beds as with percolating filters, and at Hanley we found that contact beds treating 200 gallons per cubic yard per day were clogged very soon, that was too much for them; but percolating filters have been treating more than double that quantity for two and a-half years without clogging.

26183. (*Mr. Power.*) Are the contact beds and percolating filters fitted with the same size of material —one inch to half an inch ?—Approximately with the same size material; in the one case it was clinker and in the other case it was saggar, but the amount of clogging was so vastly different that it showed at once that the advantage was altogether in favour of the percolating filter.

26184. The percolating was the clinker I suppose ?—No, the percolating was the saggar. And we might qualify the answer to question 26101, where we gave £4,500 per acre as the cost of contact beds. That is correct for Hanley, but there the cost was reduced by using clinker from the destructor close by, and the works were of a temporary character, and therefore not so substantial as they usually would require to be, so that that figure should not be taken as representative of the usual cost. Question 26105—I think, perhaps, I might read that answer, as it makes the answer I just gave rather clearer. "The best material is crushed saggars, this being a waste product in the Staffordshire potteries; and the best size for this material is from a quarter of an inch to half an inch. But almost any hard material that will not disintegrate appears to answer the purpose, and good results are being obtained from clinker, granite, gravel, slag, and blue brick, though the best size for different materials varies considerably, the object being to regulate the size of the interstices rather than the lumps of material itself, so that a mixture of large and small lumps may produce the same effects as a uniformly smaller size. A uniform size is, however, more easily defined and regulated." And the next question we have is important, No. 26106. The answer we gave is—"Excellent results are obtained from septic tanks and filters five feet deep at Hanley, and an analysis of samples of effluent taken at a depth of fourteen inches from the surface show 90 per cent. of purification, measured by the reduction of albumenoid ammonia, and 89 per cent. by oxygen absorbed." That we consider a remarkable result, and one which tends to show that the perfection of distribution which we have secured at Hanley does have an important effect upon the results. We have there been able to efficiently treat two hundred gallons per superficial yard, one foot deep, with a good effluent, which is the same thing as six hundred gallons per cubic yard, which is far more than we have been able to treat elsewhere under similar conditions, but with less perfect distribution. And we have, Sir, some photographs of the method of distribution, which, perhaps, you might like us to show, especially to the Commissioners who did not visit those works (*photograph produced*).

26185. (*Sir William Ramsay.*) I should like to ask, is there a plentiful supply of saggars ?—There is so far a plentiful supply of them. Since the Hanley works showed the saggar to be so successful we have recommended it to three other places, and we think the demand is equal to the supply now. (*Mr. Willcox.*) When we first started we charged 6d. a load to the manufacturers to tip them on the works. We now have to pay about 2s. 9d. a load for

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it. (*Mr. Raikes.*) Even at that price it is better than anything else we can get locally.

26186. (*Chairman.*) It is limited, of course, in that respect?—(*Mr. Willcox.*) It is limited, but at the present time the pottery towns of Burslem, Longton, Fenton, Newcastle, and Hanley are all using saggars, as well as several villages round, therefore there is a great demand at the present moment, whereas they have been accustomed to make spoil banks of it.

26187. (*Sir William Ramsay.*) Of course this demand will fall off, because when the contact beds have been made they will not want renewing?—No, that is true; the demand may fall off and probably will, and were it not for the question of freight no doubt it would be largely used all over the country, because at 2s. 9d. a yard for raw material it is cheaper than almost any other material you can obtain. If you got prepared clinker it would be far more expensive—5s. or 6s. a yard. As to the freight, we have enquired the price of the freight from the potteries to Stratford-on-Avon for the purpose of the works there, and the very lowest was 7s. or 8s., whereas we are getting other material, that is clinker, at about 6s. 6d. or 7s. (*Mr. Raikes.*) I thought possibly you might like us to show a diagram of the distributor at Hanley, which would explain its working. (*Diagram exhibited.*) That is just a perspective view of one of the filters, showing how the filter is supplied with sewage by a central carrier or iron trough, and the distributor consists of a pipe extending the full width of the filter, which is fed by means of syphons from that trough, and is drawn backwards and forwards from end to end of the filter by a wire rope driven by an electric motor, and the sewage flows along that pipe and escapes through a number of small nozzles or jets over the whole width of the filter, the effect being that each superficial yard of filter treats 200 gallons per twenty-four hours, and has a dose of one gallon every seven minutes 200 times a day. And we find by that means that the sewage falling on the filter acts in the same way as the piston of a pump in drawing down the air in the interstices of the filter each time, and although it only takes a very few minutes to pass through the filter we have, as already stated, got 90 per cent. of purification fourteen inches from the surface, and that is we think largely due to having sufficient time for aeration between each dose.

26188. (*Chairman.*) What is the interval of time between the moment when the tube has passed the line once and then returned to it?—Seven minutes.

26189. (*Mr. Power.*) The depth of the filter is five feet?—The depth of the filter altogether is five feet, but samples have been taken at depths of one foot, two feet, and three feet from the surface; and we find, in fact, that the amount of purification is so great in the first foot that very little remains to be done in the other four feet.

26190. (*Colonel Harding.*) On that point I should like to ask you. You have told us that at a depth of fourteen inches you were able to obtain a sample which showed 90 per cent of purification. How was the sample obtained?—It was taken in one of the effluent chambers or inspection chambers in the filter, and through the wall of that chamber a pipe was put in connected on the other side—that is in the filtering media—with an iron trough which extended for some distance under the surface of the filtering media; so that sewage falling down from the surface can get into that trough, and can be drawn off by means of a tap or pipe connected with the trough. It is really a trough buried in the filtering material.

26191. And might not that trough have contained the liquid which you analysed for a long period?—Oh no, that is not so; it is running continuously; the tap is never closed for long.

26192. Are you satisfied that the sample you took was a fair sample of what was passing through the filter at that depth?—We are absolutely certain of that; we have fully satisfied ourselves.

26913. You have told us that you have had an analysis taken at different depths?—Yes.

26194. Well, at the same time that you took a sample at different depths, did you also take sample of the result of passing it through the whole depth of five feet?—Yes.

26195. Then what was the difference between the two; the one was ninety; what was the other?—I have not got the others worked out in percentages, but it would only be one or two per cent more.

26196. Does it not strike you, if fourteen inches give 90 per cent, it is scarcely necessary to go to the cost of more?—That is the conclusion.

26197. Do you suggest to us that a depth of fourteen inches is sufficient?—No, sir, we do not suggest that as a general rule, but had we got the experiences we have now when these works were originally designed, we should probably have been able to persuade the Local Government Board to accept less than five feet deep. But we had not got it, so we could not persuade them. Though we got this result at Hanley, it does not necessarily follow that the same depth will do at other places; but we merely mention it as illustrating the point we consider of the utmost importance, that the amount of work done in a filter is very much greater in the surface layers than in the layers below the surface.

26198. This is a matter of very great interest. Can you tell us on what number of analyses your opinion is based?—I cannot give you the number. All these analyses were made by Dr. Reid, but they have been very considerable in number. I think they have been taken every week for the last six or eight months.

26199. At different depths?—At different depths. I could in a very few moments make you a sketch showing how that is arranged.

26200. It will suffice if you give us the opinion that the result of the work that is done at fourteen inches is based upon large observation?—That is undoubtedly so.

26201. And that is an opinion you are prepared to stand by?—Absolutely.

26202. And possibly while you might not recommend that a filter should be reduced to fourteen inches, you would be prepared to recommend that it should be reduced considerably below five feet?—It seems to indicate to us that the present Local Government Board standard, if it might be called a standard, which is calculated on cubic capacity alone, is not good, because very often a filter may be made six feet deep, and it would do no more work than if it were half that depth, although it might cost twice as much. (*Mr. Willcox.*) You quite understand of course that these experiments are on the filters fed by this distributor, and it is very largely a question of uniform distribution. (*Mr. Raikes.*) As the result of our practical experience, we would be the last people to suggest a general conclusion from a particular instance, but we do find this is a good example of what we have often suggested.

26203. But there is another point besides the one mentioned, that the material used in this case is very fine?—Yes.

26204. Yours are saggars?—Yes, and no large particles.

26205. You have no practical experience of the working of a filter of not much more than a foot, or considerably less than five feet?—We have not. We have for a long time been anxious to try the experiment, but since the Local Government Board insisted that the capacity of the filters should be based on their cubic contents, the cost would be prohibitive if we were to arrange 1,000 cubic yards in filters one foot deep. They would probably cost very much more than if they were arranged in filters five feet deep. (*Mr. Willcox.*) As a matter of fact we are putting down four high level filters and two low level filters for dealing with the whole of the sewage at Kenilworth. These are two feet and two feet nine inches respectively, so, in the course of a month or two, we shall have results from that.

26206. And these are percolating filters?—These are percolating filters.

26207. With saggar material?—No, granite and rotary distributors. I think we should point out that the new distributors which are being put down at Hanley differ in some respects from the old ones. In these filters you see the water, instead of passing in jets over the bed, is discharged in a continuous film the whole width of the bed.

26208. I was going to ask you a question on that. I think you have given the information I wanted to get at.

Have you not found the holes liable to stop and cause much trouble ?—No, by adopting this method we are able to use large holes, and yet have good distribution.

26209. I understand in that improved distributor you still have holes ?—Yes, but larger holes than formerly.

26210. They are larger holes ?—They are larger holes, but the tank effluent which is passing through the hole is discharged on the bed in the form of a film.

26211. (*Chairman.*) What is the distance between the holes ?—Five inches I think it is.

26212. You get a continuous film with that ?—Yes.

26213. (*Colonel Harding.*) The streams from the larger holes impinge upon a plate, which then causes it to distribute itself ?—In fan shape like that. (*Mr. Raikes.*) So instead of endeavouring to get that even distribution by putting the holes nearer together and having very small holes, we are able to do it by having the larger jets five inches apart.

26214. What is the diameter of these larger jets ?—It is three-fourths or five-eighths of an inch. (*Mr. Willcox.*) It is five-eighths ; it has been the result of experiment. (*Mr. Raikes' explaining diagram.*) That shows the central section of the feed trough, and the syphons by which the sewage is drawn out of it into this travelling distributor ; and these are small pipes or jets through which the water escapes in the original design. But we have now arranged them so that the jets come out like this, and each jet simply impinges on a small iron plate attached to the bottom, and that has the effect of making them form small fans, and then the fans just meet each other, so the sewage falls on the filter in a very thin film over the whole width, and it moves gently backwards and forwards covering the same area every seven minutes.

26215. Have you found that an advantage over the system in which the sewage passed over a lip, in operation at Hanley at the time of our visit ?—(*Mr. Willcox.*) It is an advantage to this extent ; we are able to use rectangular distributors instead of circular ones, and therefore a less area is occupied. The Scott-Moncrieff distributor was driven by means of an oil engine, which weighed itself six or eight tons.

26216. The special point I was on was, that in the Scott-Moncrieff filter the distribution was not through holes. That applies equally to the rectangular system as to the circular ?—Yes.

26217. I am not suggesting that the feeding over a lip is better ; I am merely asking you whether you have concluded that this splashing arrangement is better than a flow over a lip ?—(*Mr. Raikes.*) We had come to that conclusion ; not so much because the splashing has any advantage in itself, but because it is more easily accomplished, for the reason that with a trough we cannot use the whole available head without carrying an immense volume of water, which means a great weight, whereas with closed pipes and jets we are able to work them under pressure, and with a comparatively small pipe we can discharge a very much larger quantity by this spraying action, and although spraying in the ordinary sense, where the sewage is thrown up into the air, is likely to cause a nuisance with a septic tank effluent, we find that with this form of jet the sewage is only discharged about two inches above the surface of the filter, and no nuisance arises at all.

26218. (*Mr. Power.*) What is the average amount of suspended matter in the liquor that is deposited by this means ?—I can give you that in a moment—about five parts per hundred thousand.

26219. Does it tend to block the holes at all ?—No difficulty is experienced of that kind at all.

26220. (*Chairman.*) The holes are too large for that, I understand ?—Yes.

26221. Five-eighths of an inch ?—(*Mr. Willcox.*) In the first experimental distributor for a few weeks in the spring we found a tendency for the small jets to block, but no difficulty arises with the improved design since adopted.

26222. (*Mr. Power.*) Can they be cleaned ?—(*Mr. Raikes.*) There is a cap at the end which can be opened and they can be cleaned from end to end. The object of having a travelling distributor of that form is this, that whereas the fixed pipes sometimes used would discharge the same quantity per superficial yard, they would only perhaps have a hole one-eighth of an inch in diameter every yard, we are enabled by this arrangement to have perhaps seven holes half an inch or more in diameter, because they are travelling over a great many yards during the day. That is, we are able to concentrate the flow over a much smaller number of holes, and therefore we get over that difficulty of clogging the holes.

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26223. Have you any experience of the use of the filter in frost ?—Yes, it has been in work during two or three years, and no difficulty has been experienced.

26224. (*Colonel Harding.*) Have you had any severe frost during that time ?—(*Mr. Willcox.*) We had nearly four days in which we had 16 degrees of frost in 1903.

26225. At what temperature would the sewage reach the filter ?—It is fairly uniform. It does not appear to be materially affected by the atmosphere.

26226. (*Sir William Ramsay.*) It would be considerably above freezing point ?—No doubt, considerably.

26227. Is the pressure obtained by having a feeding trough at a considerably higher level than the feeding pipes ?—(*Mr. Raikes.*) It is about one foot above.

26228. That would give a foot of pressure ?—We get about one foot head to work with.

26229. It syphons over ?—It syphons over, that being the only method by which we can get it into the distributor without passing through the side of the trough. (*Mr. Willcox.*) It is a travelling syphon.

26230. (*Colonel Harding.*) And with that kind of distributor do you think half an acre large enough for filter beds ?—(*Mr. Willcox.*) Yes. (*Mr. Raikes.*) We have found it convenient to limit the size to that ; if the size were greater it would involve increased cost per acre. Might I ask Mr. Willis to show the second photograph after the one which he showed before, the last one in the book in fact.

26231. If the increase were in length and not in width it would not involve additional expense except in counting the radius, would it ?—That is so, but they would have to make the distributor run with greater speed in order to give the doses with the same frequency.

26232. The limit is regulated then by the interval of intermission, which must not exceed, say, seven minutes ?—The length is limited by that, and the width is limited by the practical construction of the distributor.

26233. We are to take it that with your very considerable experience in this rectangular distributor you do not advise above half-acre units. (*Mr. Willcox.*) That is so.

26234. (*Chairman.*) Would you kindly continue, Mr. Raikes ?—(*Mr. Raikes.*) Question 26113.

26235. "Have you made any study of the conditions of aeration of percolating filters ?" And we answer "A fresh supply of air is drawn down into the bed of the filter after each dose of sewage is applied." We would like to add on to that answer, "The carbonic acid gas being drawn off at the bottom with the effluent," and we consider that of great importance, because so frequently it is not provided for and we find that with this method of distribution the circulation, if it can be called circulation of air, is downwards through the filter, and that the induced current caused by the flow of water into under drains is a very effective means of removing the carbonic acid gas or other gases that might otherwise accumulate in the filter ; they flow away with the water. (*Mr. Willcox.*) And that is an argument rather against the use of raised floors in the filters. (*Mr. Raikes.*) Yes, that is certainly so. 26124 is the next one here. In regard to the difficulty that arises on acccount of any vegetable growths, we might perhaps mention our experience at Hanley, where under identical conditions of distribution it was found that with three or four different sized materials used in the same filter, the larger sizes became quite green, whereas the smaller sizes remained quite free from it.

26236-7. What was the material ?—The filtering medium was saggar.

26238. I think what the question refers to is rather growths of the sewage fungus style ?—Well, sir, that we

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perhaps did not answer correctly; we have not had any trouble owing to the sewage fungus growth, but we have observed this green colour.

26239. Fungoid growths generally?—I have not observed that.

26240. (*Chairman.*) You have not had any?—We have had none, but we have seen contact beds which are covered with green growth which we concluded was rather favoured by the fact that in contact beds the surface material is very seldom submerged, and therefore the conditions are more favourable to the growth of the green moss. I daresay that is not the growth which was referred to.

26241. Yes.—Question 26129 is the next one. "Could you express an opinion as to how the number of gallons would vary with variations in the strength of the tank liquor?" "On what figure or figures would you rely for defining the strength of the tank liquor?" and we say, "The quantity treated per super yard may to some extent vary with the strength of the tank effluent, but not in direct proportion. There is not merely the actual water logging which must be avoided, but the reduction of air space, that is to say, the more water you are putting on a filter the less air it can retain for purification purposes. The strength of tank effluent can best be defined by suspended matter and oxygen absorbed." We wished to make that clear, that in considering the quantity of sewage which a filter is capable of treating it is not only what it will take, what will go through it, but the larger quantity actually reduces the capacity of the filter, the filter really is capable of doing less purification when it is treating more sewage, irrespective of strength. It is rather a difficult point to make clear, but I think the Commission will understand what we mean by that answer. No matter how weak the sewage is there is a limit to the volume that can be treated per super yard without preventing aeration. 26130, "What is your experience of storm water filters?—Storm water filters which are only used occasionally do little more than remove solid matters in suspension by mechanical straining and for this purpose a fine shallow bed is better and less costly than a coarse deep one." That is providing that our former suggestion of working ordinary filters at an accelerated rate is not adopted. That we think is a better method than separate storm filters.

26242. That really means that storm water filters in your opinion are inefficient?—Undoubtedly; the mere fact of their being restricted in their use to storm water makes them inefficient, whereas they might be used with greater advantage if kept in regular work.

26243. (*Major General Carey.*) But they can be used if necessary by the regular sewage from time to time to keep them in a state of efficiency?—(*Mr. Willcox.*) As a rule they have no proper means of distribution, and with the ordinary storm sewage filters the sewage is brought on to them and distributed from a wooden trough, and uniform distribution is impossible by a wooden trough.

26244. (*Chairman.*) You can only depend upon the storm water filters to remove certain solid matters, not to bring about such purification that the effluent could be discharged without danger?—(*Mr. Raikes.*) That is so, sir, and the saving effected by constructing them in an indifferent way is not at all proportionate to their inefficiency.

26245. (*Colonel Harding.*) Mr. Raikes, you have just expressed to us an opinion that you did not like a special filter for dealing with storm waters, and that you think it is better to increase the flow on the ordinary filters?—Yes.

26246. But did you not tell us that it was undesirable from your experience to increase that flow more than 100 per cent?—That is so; we are rather anxious to make it clear that in giving that answer we assumed that the filters were designed for treating three times the dry weather flow, and therefore it would only be necessary to increase their working by 100 per cent. in order to treat six times.

26247. (*Sir William Ramsay.*) I suppose you think there is no disadvantage in working the filters slower than they ought to be worked?—Not at all; we should think that that is not a disadvantage, providing they are not given too long a period of complete rest in which their activity would be reduced.

26248. Supposing your filters were designed for three times the dry weather flow, and worked at one third the rate, in ordinary circumstances you think those filters would be kept alive and well used, I suppose?—Oh, yes, we should think so; we would like to have an opportunity of explaining at the end of our evidence a method by which we could equalise the work between the different filters in that way. Question 26136 "Is one standard for all effluents passing into non-potable streams possible and desirable, and if so, what should it be?" And we answer, "Different standards are required for different watersheds, but all might perhaps have certain points in common, such as the absence of suspended matter and the amount of oxygen absorbed." We have the impression that your Commissioners are interested in the question of standards, and as we have considered it a great deal, perhaps, the Commission would like to know the results of some notes we made on that subject. We have felt that the determination of even a local standard would involve the consideration of a great many points which affect the classification of the rivers and streams into which the effluent is to be discharged; and we have made a list of the different points that would arise in that connection, of which, perhaps, I might hand you copies.

26249. (*Chairman.*) Will you read them first?—I will read them first. "The points to be considered in connection with the classification of rivers and streams: "*Characteristics of watershed*—Area and configuration, geology and underground water, duration and rate of rainfall, evaporation and run off. *Measurement of quantity and quality*—Object and nature of observations, variations in depth and discharge, variations in chemical analysis, variations in bacteriological analysis. *Methods of measurement*—Fall, rapids, lakes, velocity measurements, Weir measurements, chemical analysis. *Causes of pollution*—Prescriptive rights, manufactures, public authorities, private proprietors. *Interests affected by pollution*—Domestic water supplies, trade purposes and irrigation, fisheries and navigation, water power and ornamental." We only mention those as showing the great number of points that we should feel called upon to consider in case it ever were our duty to advise anyone in regard to the establishment of a standard, that we should not at all consider it practicable to fix a standard for the whole country, and even the adoption of standards for districts or rivers boards could only be made approximately fair after considering the different local conditions.

26250-1. That means that you would have a standard almost for every set of works?—Well, sir, we rather had in mind that, if the idea of rivers boards which we have here mentioned were adopted, it would be within their power to fix an arbitrary standard, which they thought would be reasonably fair for their districts. It would be impossible to arrive at an ideal arrangement which would suit everybody, but it would be much more nearly fair than if one standard were fixed for the whole country. (*Mr. Willcox.*) Take the potteries for instance, all the towns in the potteries drain into the River Trent. A standard would be fixed for this having regard to the conditions there. (*Mr. Raikes.*) One standard would perhaps be suitable there, but perhaps quite a different standard would be suitable for London for instance.

26252. Then there is nothing else till the last question of all, 26141. We have already said that we look upon the method of controlling the works as a very important one, and I might read the answer to that question. "Since it is found that in order to obtain the best results from bacteria beds, it is of the utmost importance that their operation should be scientifically controlled by a skilled chemist, we have devoted special attention to devising a means whereby the control of the Hanley works should be centralised as far as possible, and should be pleased to submit and explain detail drawings showing the methods to be adopted for (*a*) measuring the total flow of sewage to be dealt with; (*b*) recording the rate at which each filter works; (*c*) for starting and stopping the distributors; (*d*) taking samples of filtered effluent for analysis. The apparatus being so designed that the whole of the above observations and samples may be taken by the managing chemist

himself at any time during day or night, without leaving the laboratory and without outside assistance, thereby eliminating the possibility of error owing to carelessness on the part of subordinates." The addition is merely that we have got the detail drawings, showing the method of controlling the works from a central station, by which the chemist or manager in charge could have everything under his own eye.

26253. (*Chairman.*) Can you show us now ?—Yes, at once (*plans shown*). That, sir, is the plan of the works at Hanley, and the site for the proposed central recorder house is shown in red in the centre, and it is our proposal that the whole flow to the high level filters should be measured by a venturi meter at that point A ; and then by another venturi meter for the low level filters at this point B. The sewage coming from the septic tanks along the main carriers to the high level beds having been measured in bulk at A the flow again to each filter is measured by another meter at the points marked M M. The same applies to the low level beds, and the results of these measurements would be registered by an automatic recording instrument placed in the laboratory at the central station, so that the man in charge would see at a glance exactly which filters were in operation, and what length of time they were working; so that, supposing, as we might assume, that during the whole twelve months the average number of filters in use continuously was four, sometimes much more, sometimes much less, but supposing the average were four, he would so operate the whole of the filters that they would all have had an equal share of work, and would not have an excessive amount on any particular filter; if any one filter showed a tendency to lose its efficiency, that could not be caused by its having done more work than the others ; at any rate without its being known. Also to take samples of the effluent, we propose that a suction pipe, a small three-quarter inch pipe should be taken to the effluent chamber of each filter at the points marked E.E., and connected to the pump in the office driven by an electric motor, and in that way a sample can be taken from any filter and analysed at once by the man who takes the sample. That plan is in operation at East Jersey waterworks in America. I had an opportunity of examining it, and found it very successful ; they entirely eliminated the source of error due to unskilled assistance in taking samples. The man in the house here would not only take a sample, but have all these records before him on recording instruments of the type usually adopted with venturi meters.

26254. (*Chairman.*) What is the distance the sample has to be carried from the effluent chamber to the office ? —The maximum distance would be about 100 yards, but since the effluent there is quite free from any suspended matter, we do not anticipate the slightest difficulty on that point. That is the house in which the instruments would be placed ; in section it is shown there, this being the high level side next to the bacteria filters, and that the low level side, the meters being all connected with vertical cylinders here, the fluctuation in pressure would be arranged to affect indicators in the office above, and the same applies to the pumps for taking the samples. The details of the recording instruments are shown on another detail drawing. That is the arrangement of the meter at the inlet of each filter, and these are the pipes brought through from these other filters beyond, and although it appears that there is rather a large number of pipes that is the filter through which all the rest pass, so that really it shows more than the average a great deal, and the section of the meter as shown there makes it clear that there is no obstruction of the flow at all, the quantity passed being accurately measured by the difference of pressure at the inlet side here, and in the front of the meter by the variation of water level of these cylinders which are connected by tubes with those two points in the meter, and that variation is automatically recorded on this clockwork diagram which can be taken off every day or every week.

At the end of the evidence, sir, we have made one or two further notes. We could also furnish information as to the methods adopted in the United States, for gauging all rivers and streams for the public benefit by a Government department, and also as to the scope of their investigation. We only mention that because I had an opportunity of studying their methods there, and I was much interested in the extensive examinations of all their rivers and the accurate gaugings and observations that were made of these rivers all over the country, so that data were always available for any scheme that might need data of that description ; and there was a method of taking gaugings which was sometimes found very convenient and quick by analysis. That is, a given quantity of some salt or chemical was put into the river at a certain point, and then by taking a sample lower down the volume of water could be estimated by analysis.

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We feel some anxiety as to the increased difficulties which might arise if rivers boards were adopted with discretionary powers to interfere with the design and construction of sewage disposal works beyond indicating their minimum requirements as to capacity and degree of purification to be obtained. We only mention that because we have not found the existing system entirely free from trouble in that direction, and if it were contemplated that rivers boards or any other river authority were required to assist or govern the design of works that were in course of development, we feel that it would perhaps involve more difficulties than now arise, when the scheme has first to be prepared and then submitted.

26255. (*Colonel Harding.*) Has any suggestion been made by anybody to give rivers boards these powers ?—I am not aware of any suggestion ; we only mention that as one which had occurred to us.

26256. As measured by oxygen absorbed your sewage at Hanley would appear to be only about half the strength of the sewages of Birmingham or Manchester, would it not quite roughly ?—Yes, I believe that is so, sir.

26257. But in another direction your sewage is peculiar, showing an exceptional quantity of suspended matter, your average being sixty-two parts per 100,000 ?—That is so.

26258. And that I think you account for by the presence in your sewage of special trade effluent, which you tell us is technically called "slip" ?—Slip.

26259. Now to what extent does the presence of this slip in your sewage facilitate sedimentation ?—We find that a very large proportion of the suspended matter is deposited in one hour in sedimentation tanks or detritus tanks ; we should quite expect that if the slip were not present it would take longer to obtain such a large proportion of deposit.

26260. Then do you find that in one hour the suspended matter which forms the slip is almost wholly thrown down ?—That is so.

26261. And probably in going down it mechanically carries with it particles of other suspended matter and facilitates sedimentation ?—We should expect that ; yes.

26262. That probably may account for the very small amount of suspended matter which at Hanley goes on to the filter bed ?—No, I do not think that would be so, sir ; I might say we have experimented with tanks ; when we had no detritus tanks as a preliminary to the septic tank, but this did not seem to make much difference to the suspended matter in the tank effluent ; that is to say, it would appear that if the suspended matter did not deposit in the detritus tank it would deposit in the septic tank.

26263. But the slip was present in either case ?—Yes.

26264. So that the slip may still have had the effect in the detritus tank which it has in the other tank ? —Yes.

26265. We are anxious to understand what the special conditions of Hanley are, because the experience elsewhere of septic tanks is that it is impossible to work them without their carrying away on to the filters considerably more suspended matter than you do at Hanley. At Hanley you told us that your suspended matter in the effluent from the septic tank averages five parts per 100,000, and that that only rises occasionally to a little over seven parts per 100,000 ?—That is so.

26266. Elsewhere we find it is not infrequent to have as much as fourteen parts or even considerably more than that at special times in the septic tank effluent ? —That we know to be the case, sir, and we are well acquainted with the Birmingham sewage farm, for instance, where a larger quantity of suspended matter comes

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from the septic tanks, and Mr. Watson the engineer to the drainage board there has so far recognised its importance that he is putting down special tanks, following septic tanks, to reduce the quantity of suspended matter.

26267. Still the fact remains that in other places that is a difficulty, that the septic tank effluent takes away with it a much larger quantity of suspended matter than you find to be the case at Hanley ?—Yes, there are some places much more and some places much less.

26268. But at Hanley your condition would appear to be rather peculiar, and that bears in a very important way upon the experience of the fine material you use in your filter beds at Hanley. Have you, may I ask, since our visit in November, 1904, found that the beds we then found working have by this time shown at any time any amount of pooling on the surface ?—None at all. (*Mr. Willcox.*) None at all; I had them examined about six weeks ago, and there was no sign of clogging except such as you saw when you were there.

26269. Then you do not find that there is an increasing difficulty in passing the liquid through these fine filters ?—No.

26270. And in short you are prepared to say that you are perfectly satisfied with the conditions at Hanley, satisfied with the very fine material used ?—Quite. (*Mr. Raikes.*) And there are several other places where fine filters are equally successful.

26271. Your experience is somewhat different from what we have had elsewhere; we are anxious to see what are the conditions at Hanley which make the use of fine material possible; and one of them would appear to be you bring to the filters an effluent containing very little suspended matter ?—(*Mr. Willcox.*) That would be so. (*Mr. Raikes.*) I might mention that I have here a list of the suspended matter tank effluents from several other places that were mentioned by Dr. Reid in his evidence before your Commission, and I see that Brownhills is given as 8; Hanley, 4·5; Lichfield, 3·6; Pelsall, which was a scheme we carried out, 5·3; Tipton, 1·6; Tividale, 7·9; Wolverhampton, 2·2; so that it would seem on those that there are cases very much higher and there are cases very much lower than Hanley.

26272. Are those from septic tanks ?—(*Mr. Willcox.*) Lichfield is chemical treatment.

26273. (*Chairman.*) The Wolverhampton one was 1·2, I think you said ?—

26274. (*Colonel Harding.*) Is that from a septic tank ?—Wolverhampton is given as 2·2.

26275. Is that from a septic tank ?—That is precipitation with lime in experimental works.

26276. That does not help us; have you many instances of effluents from septic tanks within your knowledge that give results even better than those at Hanley ?—(*Mr. Raikes.*) At Pelsall the septic tanks and filter are much the same as at Hanley and we have five parts per 100,000 of suspended matter in the tank effluent.

26277. Then is that an ordinary septic tank ?—That is an ordinary septic tank with filters of fine material.

26278. Without a detritus tank ?—Yes, there is a detritus tank there.

26279. What is the nature of the sewage ?—(*Mr. Willcox.*) Purely domestic sewage. (*Mr. Raikes.*) There is no slip or exceptional condition there at all. (*Mr. Willcox.*) It is a colliery district.

26280. Also from a long average ?—Yes, from a long average.

26281. (*Colonel Harding.*) That is the only case I think mentioned dealing with domestic sewage, where the results are so small a quantity of suspended matter ?—Most accurate records were kept there by the surveyor and analyses made regularly for a long period—five or six years—and it would be quite easy to obtain information there. (*Mr. Willcox.*) At Brownhills an adjoining district, also a colliery district where there is a brewery, suspended solids are 8.

26282. I should like to return for a moment to what you told us about treatment of storm water, and your recommendation that the filters in current use should be used with an augmented flow dealing with storm waters, and you told us that it was quite possible to increase that flow by 100 per cent, in other words to double it, and that you are able to deal with those volumes because you base your area of filters upon three volumes, and therefore by doubling it you deal with six volumes. Now what do you mean by that ? What is the rate of flow per superficial or cubic yard which should be adopted as a sort of standard, is it not 200 gallons per superficial yard; do I understand that that is a rate which will only be obtained when three volumes are passing on to the filters, and that under normal dry weather flow conditions what you deal with is one-third of 200 ?—Yes, but I might qualify that so that I might not be misunderstood; it is quite true that only 200 gallons are put on per super yard on the whole area of the filters when three times the dry weather flow comes, but we should find it quite impracticable to distribute one-third of that quantity on the whole area affected. The area in operation is reduced not the rate of distribution.

26283. I quite appreciate that; then I may take it that you would only use in ordinary conditions one third of your area ?—Yes.

26284. (*Sir William Ramsay.*) You would use it intermittently, I presume ?—That is so, sir; we should endeavour to equalise the work; supposing there were three acres you could use them in rotation. (*Mr. Willcox.*) Instead of retaining one acre for the dry weather flow.

26285. But again before we leave that point, by reducing the depth of your filter, say, to three or two-and half feet instead of five feet you would thereby effect a saving. Of course your superficial area would be the same, but you would effect a saving in the case of the filters ?—(*Mr. Raikes.*) An enormous saving. (*Mr. Willcox.*) But you must have efficient distribution if you do that.

26286. That is an important point ?—That is a very important point.

26287. (*Major General Carey.*) Can you explain on what basis the average daily dry weather flow of sewage has been estimated ? On the basis of the water supply of 25 gallons per head, it amounts to 1,500,000 gallons per diem ?—Yes.

26288. But your estimate of 3,600,000 of course is very considerably more than that; in fact it amounts to over 50 gallons per head of the population ?—It does, yes.

26289. I should like to know how that margin is accounted for ?—That is explained in the evidence; there is a large quantity of water from mines; it is pumped into the sewers and steps are being taken now to divert from the sewers 1,000,000 gallons per day pumped from the mines; it is a mining district you see; and some of the old outfall sewers consist of brooks which from time to time have been covered in and formed into sewers; the mines had the right to turn the mining water into those streams and when the streams were covered over the mine water still continued to flow down the streams to the outfall works.

26290. (*Chairman.*) That is being now diverted ?—Yes, steps are being taken now to divert this mine water and carry it to the streams.

26291. (*Major General Carey.*) Then your sewage will become stronger ?—Yes.

26292. And your dry weather flow will be the amount of the sewage proper ?—Plus the water from the pottery works, etc.

26293. Effluents and trade water ?—Effluents and trade water; it would be reduced to 2,500,000 probably. (*Mr. Raikes.*) I might say although we answered the question there by giving the actual flow of sewage as 3,500,000. For the purpose of our calculations in designing this scheme, we have allowed for the reduction of the sewage by the elimination of this mine water, so that it would appear that our figure is too high. We quite appreciate that, and we have allowed for that apparent error in our calculations and our works are designed for what the sewage will be in volume when they are completed (*Mr. Willcox.* When the mine water is taken out.

26294. The maximum winter flow really consists of the normal sewage and the storm sewage of the winter and the mine flow ?—That is it. That accounts for the large volume. (*Mr. Raikes.*) If we did

not make provision for that it would involve a very great error in our calculations, but we have allowed for it; our scheme is based on 2,250,000 gallons a day dry weather flow.

26295. Question 26021. "Generally speaking, yes; but in the absence of very exceptional circumstances no untreated storm sewage should overflow from sewers into any water course until the flow in the sewers exceeds a rate equal to three times the maximum dry weather flow." Is that a general opinion or merely applicable to this specific case?—It is, in regard to Hanley particularly, but it is capable of fairly general application. It is impossible to draw hard and fast lines which will be right in every case.

26296. In a great many cases the storm sewage comes down at a rate of, say, six times the dry weather flow?—Yes.

26297. Would it be sufficient to take three times the dry weather flow, to the outfall works, and put the remainder into the stream?—That is just the distinction, you will see we have mentioned the maximum, three times the maximum dry weather flow.

26298. The maximum dry weather flow?—Yes, but you see at present time the Local Government Board generally require the overflows to come into action where six times the average dry weather flow is reached; we assume, as I think we fairly may, that the maximum is rarely double the average.

26299. But in this case is your maximum the maximum dry weather flow?—Yes, but I was wishing to make that quite clear, that we do not suggest allowing the storm overflows to come into action when three times the average dry weather flow is going to the outfall. We say three times the maximum dry weather flow, and in practice we anticipate that that would mean about six times the average dry weather flow.

26300. Oh, is that it?—We have no reason to complain of the course taken by the Local Government Board in fixing six times the average dry weather flow, except that it does not take any account of the hilly or flat districts by fixing the basis as the maximum instead of the average. We have taken that into account.

26301. With regard to Question 26082 I do not understand the contact bed periods: standing full, nil. That means that there is no contact?—Not counting the time occupied in filling.

26302. Filling and emptying; it is going right through?—Our reason for putting it that way is just this, that we feel that the purification in the contact bed is proportional almost to the amount of air contained in it, and when that air has been expelled by filling the bed with sewage, under ordinary conditions not much more purification takes place afterwards, and we have not been able to find that any advantage results in keeping the sewage in the bed for a longer period after it has been once filled, unless there are some exceptional conditions such as trade waste, or some question of that kind which may alter it. But generally we find that the best results are obtained by making the period of aeration as long as possible, and the other three phases of the series as short as possible.

26303. There practically is no contact, except the amount of time in passing through the filter, in filling and passing through?—That is so.

26304. The moment it is filled you begin emptying; is not that it?—Yes. Perhaps that is rather a development of the argument that is in our mind, that much of the purification which takes place in contact beds is frequently due to the percolating action while they are being filled, and if that is the case of course the period of contact would not affect them.

26305. Generally in your replies I gather that you are strongly in favour of percolating filters as against contact beds, that they are quite as efficient and less costly in the long run to the public?—That is decidedly our opinion. We are advising or have recently been engaged on about sixty different schemes in different parts of the country, and we have found that they are invariably more satisfactory in our experience.

26306. As to the oxygen absorbed test, 26136, does this test give in your opinion any accurate measure of the organic matter in sewage?—That is rather a chemical question, which we as engineers feel rather diffident in answering. We have simply suggested it as a practical thing that we can more easily understand; more easily than the others.

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26307. (*Sir William Ramsay.*) I should like to ask in that table 26006, how the average samples were drawn. Were they taken in accordance with the rate of flow of the sewage?—No, I do not think they were I think they were simply taken from the sewage each day or whenever it was. I do not think any allowance was made for that.

26308. Question 26026. You assume that road water need not be treated. Is there any reason for that assumption, because we have had evidence that road washings are very polluted?—We appreciate that, sir, and our answer is rather framed on account of the practical difficulties of carrying out any treatment, than the disadvantages of doing it if it were practicable. We admit there is a certain amount of pollution in road washings, but it would involve a colossal scheme to provide for them all. First washings might be separated with advantage by leaping weirs, and treated.

26309. As to question 26027, do you know about these samples of Dr. Reid's? Are they chance samples?—No, they are the result of a number of samples; I can not tell you how many.

26310. An average?—An average.

26311. Are they public?—I think they were contained in his paper (*Mr. Willcox.*) The paper he read before the Sanitary Institute of Glasgow.

26312. Regarding question 26038, at what places were your observations made which tend to show that a chemically treated liquor has a greater tendency to clog filters?—(*Mr. Raikes.*) At Hanley we were called in to inspect their existing works, and we found that the land filters that had been in use for some years with a chemically treated tank effluent, that is, lime was used for precipitation, that land had been practically converted into concrete, and that was the reason—(*Mr. Willcox.*) That all applies to Hanley only.

26313. The lime alone?—The lime alone.

26314. Then would you mind telling us how you draw your samples generally from which you calculate the tank digestion and the percentage of purification of the effluents. With reference to 26056, as regards the amount of digestion of sludge, one would like to know how the samples were drawn from which you calculate the amount of digestion in the tank?—It was calculated partly on our own observations and partly on those of Dr. Reid. He analysed the sewage and showed the amount of suspended matter including the solids in solution and suspension coming into the tank.

26315. On the average?—We measured the quantity of sludge which accumulated in the tank.

26316. Dried it and took its dry weight?—We took it in that way.

26317. How did he get his average; I suppose simply analysing it every day?—That is so, whether every day or twice a week, at any rate, at uniform intervals. (*Mr. Willcox.*) He sends his river inspector over once a week I think, and he spends a day there. That is practically how the samples were taken.

26318. So that they are practically weekly samples?—Yes.

26319. Question 26091, you say the cost of washing the materials should not exceed a shilling per cubic yard. Is not that very little?—That is based on our experience of the actual cost of washing material, not after it has been clogged but before putting it into the filters, and we think that without the cost of buying water that is quite sufficient to cover it. We could certainly do it for that sum. (*Mr. Willcox.*) We are paying 8d. a yard at Newcastle-under-Lyme for washing saggars.

26320. Are the saggars generally washed before they are put in?—No, they are washed there for this reason. The Newcastle Corporation accumulated a large heap of saggars. They accumulated them during the winter. The result was they got wet and dust adhered to them. We had to wash them to remove the dust.

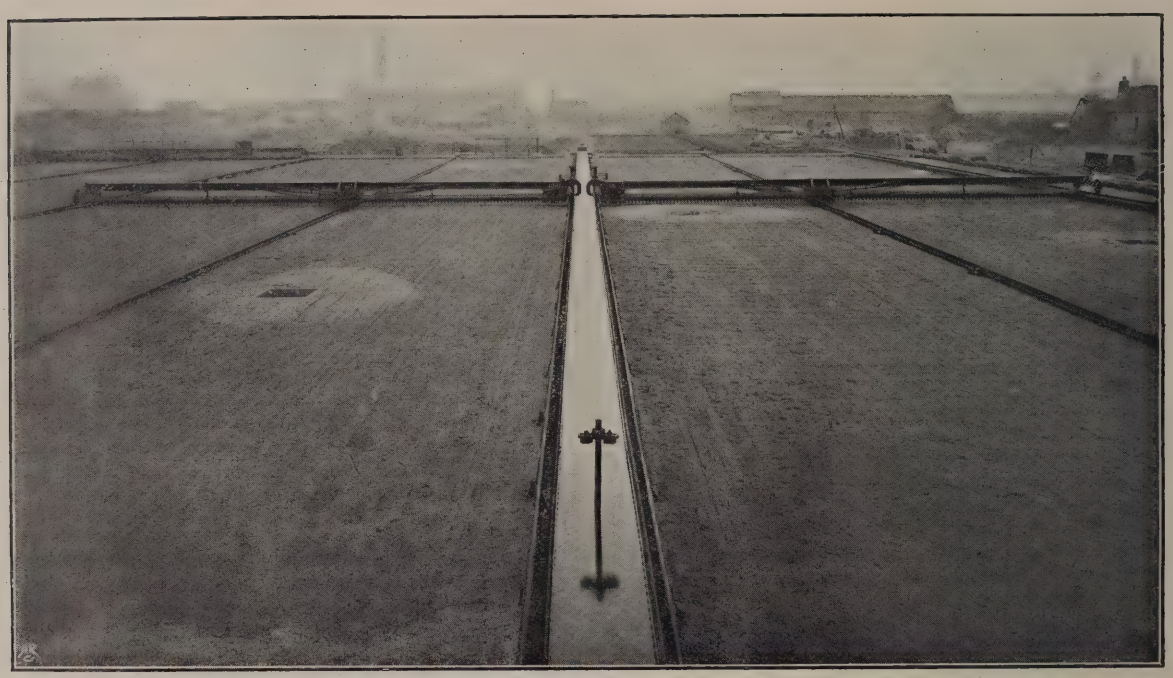
26321. Would not the cost of washing them after being used in the filter be considerably more?—More than 8d. a yard; probably 30 per cent. more; we say a shilling.

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(*Mr. Raikes.*) I might add that a great difference would be effected by the filters being allowed to go on too long. If a filter were left till it was absolutely clogged and full of solid matter, it would be necessary to take the whole of it out and wash it, which would undoubtedly cost more. We did not contemplate allowing the clogging to go on, but to wash the surface layers before it went so far.

26322. Referring to question 26120 and the table, are those figures there the average sample?—Yes, those again are based on Dr. Reid's figures.



Willcox & Raikes Distributor for ½ Acre Bacteria Bed at Hanley.



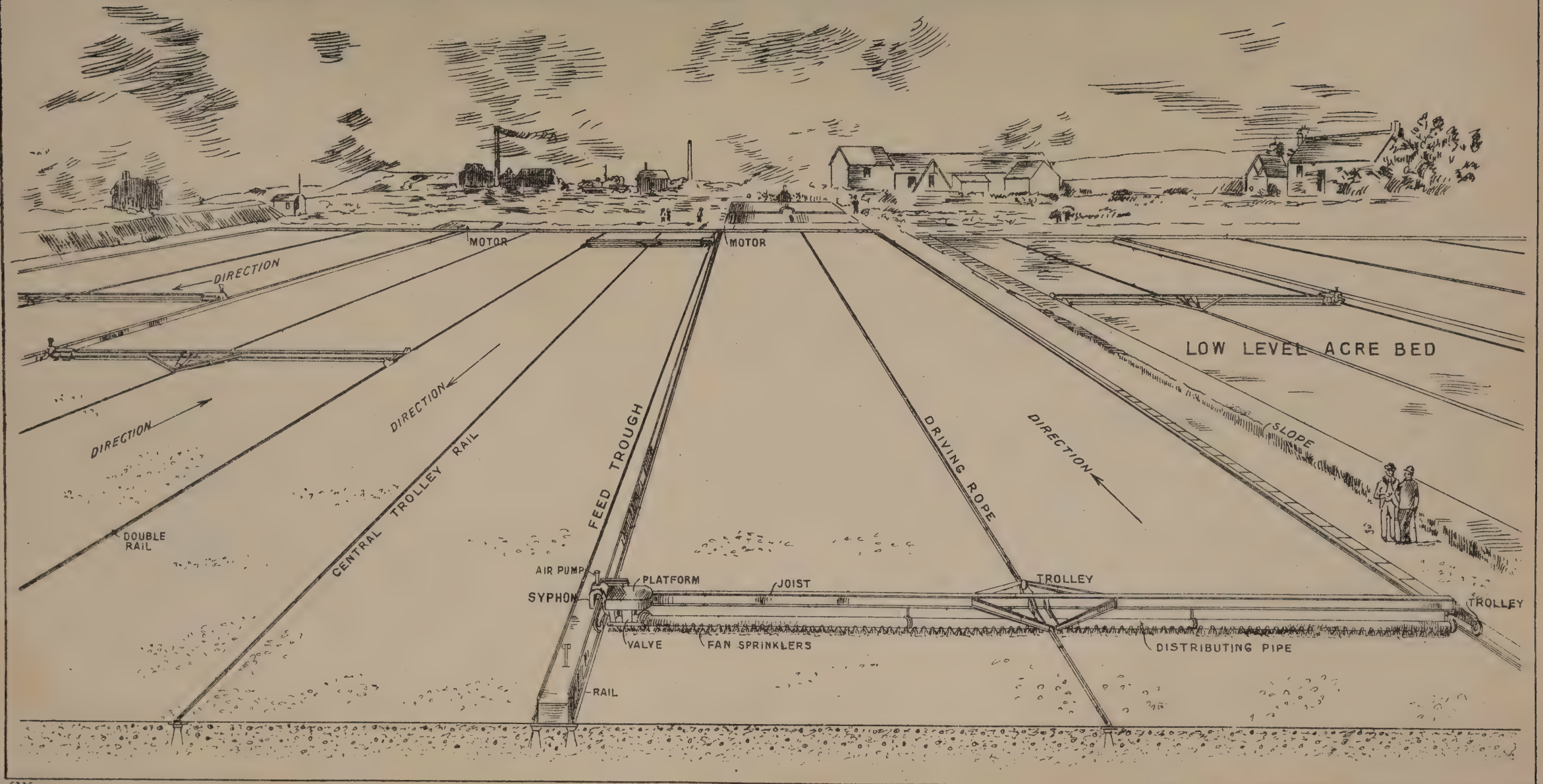
Willcox & Raikes Distributor for ¼ Acre Bacteria Bed at Hanley.

ROYAL COMMISSION ON SEWAGE DISPOSAL

DRAWING Nº I.

Handed in by Messrs Willcox & Raikes.

WILLCOX-RAIKES SEWAGE DISTRIBUTOR AT WORK ON ONE ACRE BACTERIA BED



5236

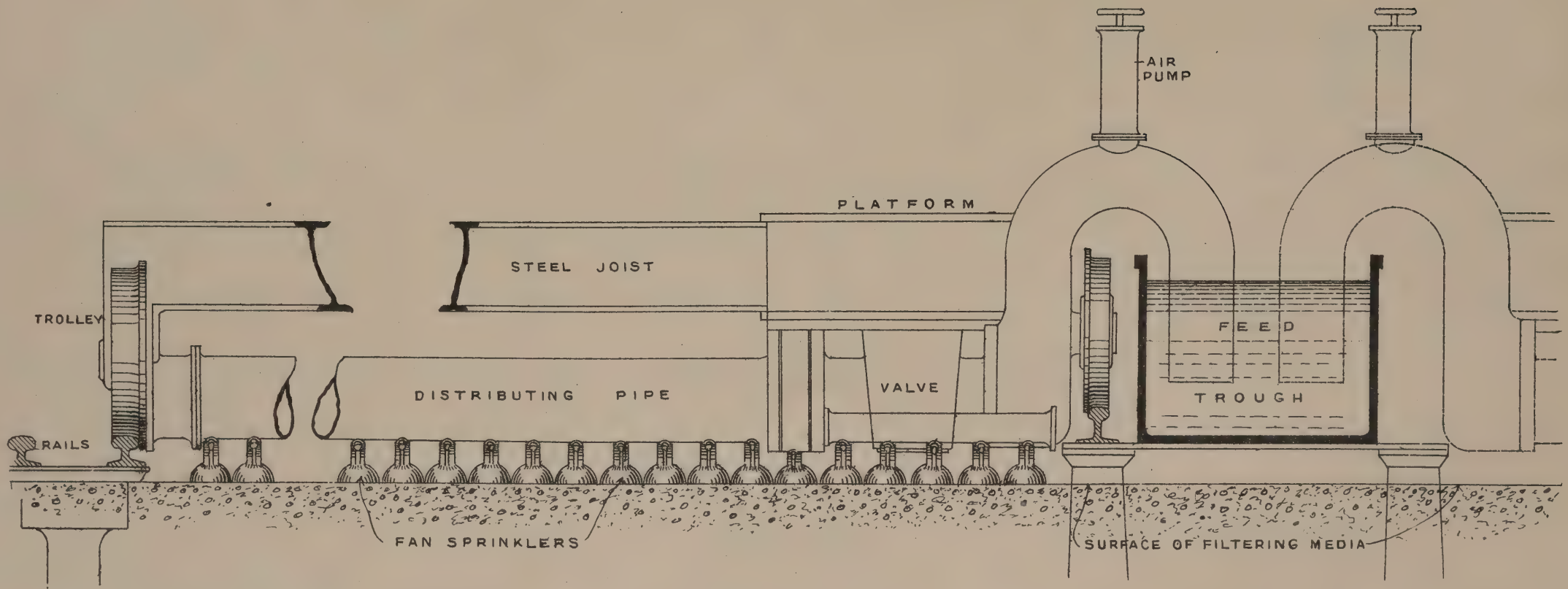
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ROYAL COMMISSION ON SEWAGE DISPOSAL

DRAWING Nº II.

Handed in by Messrs Willcox & Raikes.

WILLCOX-RAIKES SEWAGE DISTRIBUTOR FOR RECTANGULAR BACTERIA BED



DETAILS

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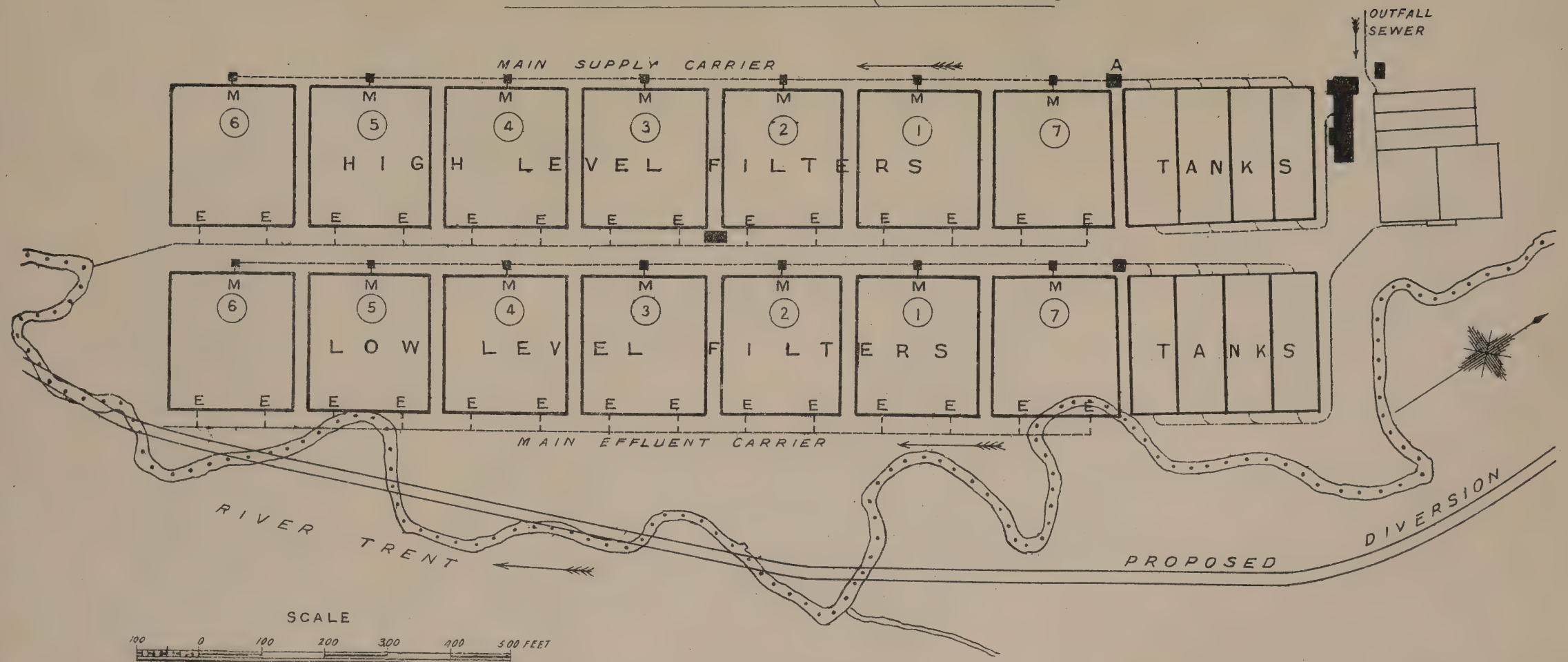
ROYAL COMMISSION ON SEWAGE DISPOSAL

DRAWING Nº III.

Handed in by Messrs. Willcox & Raikes

HANLEY SEWAGE DISPOSAL

PLAN SHOWING SYSTEM OF CENTRAL CONTROL FOR FOURTEEN RECTANGULAR BACTERIA BEDS (ONE ACRE EACH)



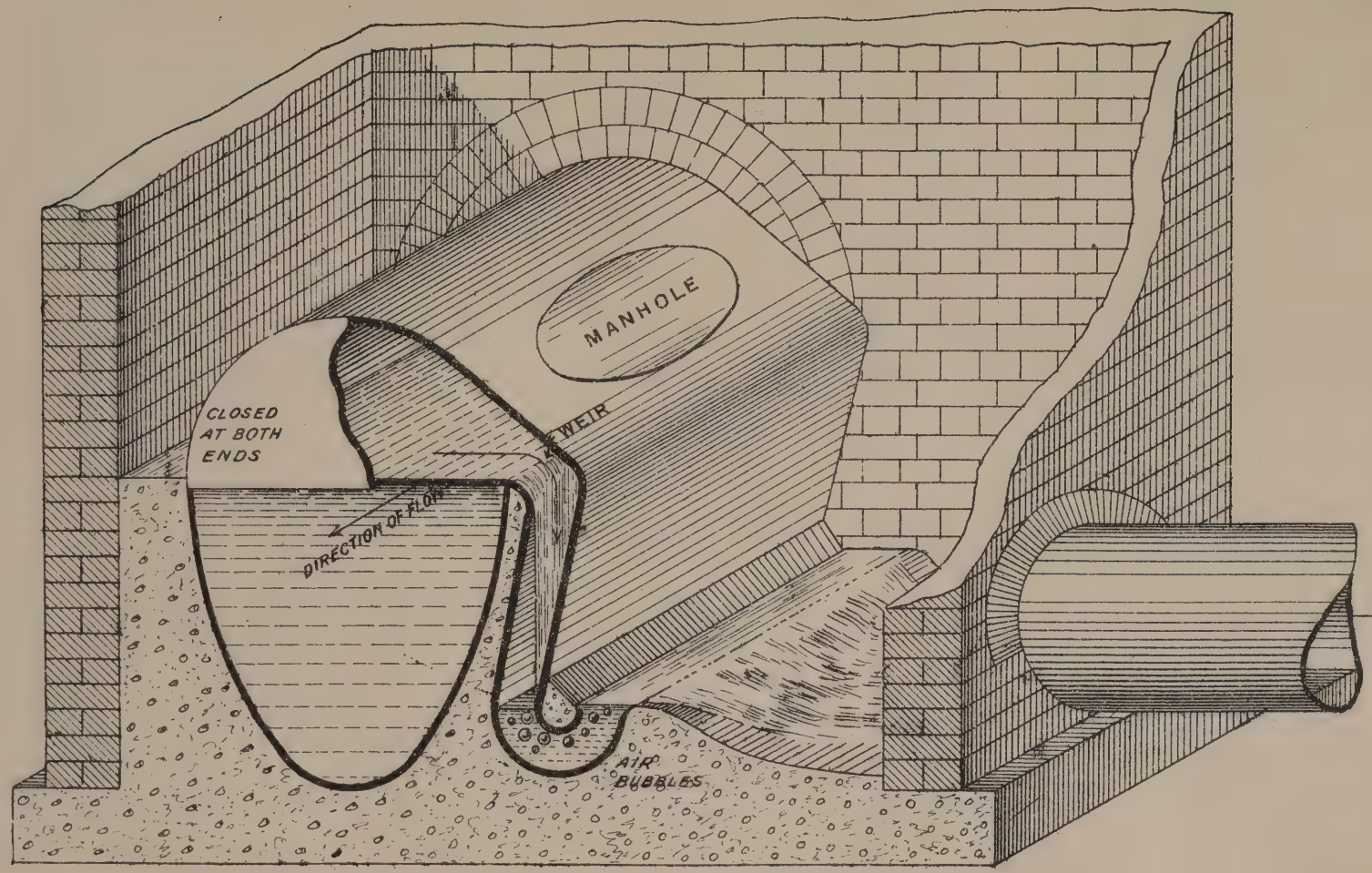
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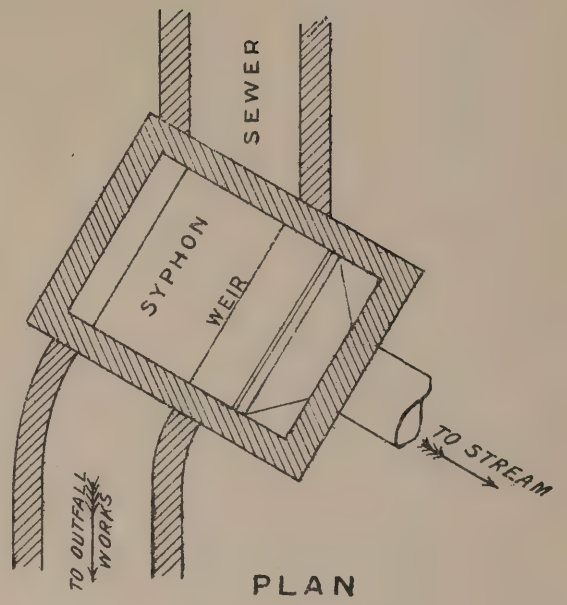
ROYAL COMMISSION ON SEWAGE DISPOSAL

DRAWING Nº IV.

Handed in by Messrs. Willcox & Raikes

VIEW OF SIPHONIC STORM-OVERFLOW.





PLAN

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Mr. JOHN HUNTER, F.I.C., F.C.S., called in; and Examined.

Mr. John Hunter, F.I.C., F.C.S.

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26323. (*Chairman.*) You are a Fellow of the Chemical Society and a Fellow of the Institute of Chemistry?—I am.

26324. You have had long experience of distillery effluents?—I have.

26325. And you say that probably you were the first to introduce evaporation for pot ale?—I think I certainly was.

26326. Might we consider first of all this subject of the evaporation process of pot ale. Now, is there a statement you would like to make to the Commission with reference to that?—I do not know that I have any particular statement to make; I would rather answer questions if there are any to be put. All I can say, is in my precognition. It is so far satisfactory, and some people regard it as being probably the only check.

26327. You say this was carried on with considerable success in Longmore's Distillery?—It was.

26328. At what date was that?—It is over twenty years ago; twenty-five years probably.

26329. But it was abandoned?—It was abandoned.

26330. Why was it abandoned?—Because distillers were not very keen upon doing anything to make waste products, and they found this a little trouble to themselves. And in addition to that they found that the feeding cake which was made from it was liable to become fungated, and it was troublesome to keep if there was not an immediate demand for it, and that was one additional reason why the process was given up.

26331. The evaporation process was somewhat different from the evaporation process worked in the Spey Valley?—At that time of course the evaporation was in open pans, and then of course dried up with grains, or grains and maize, &c.

26332. Made into cakes for cattle?—Into feeding cake, yes.

26333. It was abandoned you say because——?—In the first place the distillers found it a nuisance. It was extra work to them, and they did not care for that; and in the next place the cake, when not sold immediately, became fungated and unmarketable.

26334. Then they adopted other methods of dealing with their pot ale?—The old method, into the stream.

26335. Which they were permitted to do?—They have been permitted up to now. They have been threatened, I understand, but I do not think any proceedings have been taken against them as yet.

26336. Although you were the first to introduce it, the process was patented apparently by others. Did you take out a patent for it?—Oh no. What was patented was simply the mixing of grain stuffs with pot ale. That of course had already been done. It was not the apparatus that was patented, but the fact of mixing so as to produce a food stuff.

26337. The evaporation process as carried on in one or two distilleries in the Spey Valley is a process which goes on much further than that?—Yes.

26338. It leads to a calcined product, does it not?—Yes.

26339. What is your view with regard to that?—A good deal of what I know is of course hearsay.

26340. Only from hearsay; you have no practical acquaintance with it?—Oh yes, I have practical acquaintance.

26341. Will you please tell us what you know from your practical acquaintance?—The desire from that process is to get a marketable commodity. The value of that depends on the extent to which evaporation and incineration is carried out. If it fires, a great deal of the nitrogenous stuff of course goes to the air, and the residual value is very much less. And another feature of it is, to my mind, that the last of the evaporation is the most expensive, and, secondly, that if the residue could be dealt with before incineration the process would be greatly cheapened, and the value of the residual product made much more valuable. Perhaps I might explain what I consider would be a feasible method of dealing with that, because I have made experiments with it at Dailuaine Distillery, with considerable success. It is drawing the residual material before incineration, mixing it with strong sulphuric acid—say 140 degrees T—so as to bring the strength down to about 112 degrees T, and then running in a cheap phosphatic material, Belgian phosphate or Algerian phosphate, which contains 20 or 30 per cent. of carbonate of lime, in the decomposition of which the sulphuric acid comes, sulphate of lime, which takes water of hydration and produces a dry product. It would be a little more trouble, but I feel quite satisfied if that were gone into it would lessen the expense materially, and would permit of the present evaporation installations overcoming all the work instead of only a part of the work as at present.

26342. And that could be done, you think, at not a prohibitive cost?—I think so.

26343. With profit?—I think so. The saving in coal, and the enhanced value of the by-product would be much cheaper than evaporation is at present, and in my opinion it could be made profitable.

26344. You say you have made some actual experiments on this?—I have, sir, at Dailuaine.

26345. With different results?—Yes. Of course it was done crudely in this respect—that we built a brick tank into which we pailed the residual matter from the evaporation column, and added our sulphuric acid so as to bring it to 112 degrees or 120 degrees, and then run in a cheap mineral phosphate, with the result, that we got a product which was quite dry in the course of five or six hours; it was perfectly dry and quite capable of being put into bags and carried away.

26346. Might I ask how far exactly you carried the evaporation?—Well, I cannot say to what extent even the gravity of the liquor was; it was a new installation.

26347. The evaporation was in pans?—No; it was the Lennox sprayer in a tower in the flues—a nozzle similar to the Strawson sprayer.

26348. The Lennox system you adopted. That goes on to complete incineration when it is carried out?—Yes, it does.

26349. But you took it to a less extent?—Oh yes it was quite liquid when I took it out, or a very thin paste, and before anything like incineration took place.

26350. That is to say, it was the Lennox system partially applied?—Yes. I may say in connection with that that I made another experiment, which has some bearing on this question of temperature and evaporation. It was worked in connection with my own process, the boiling process, this Lennox tower at Dailuaine. In order to cheapen the boiling process, I introduced a mineral phosphate, that is called fossil phosphate, which contains from 70 to 80 per cent. of carbonate of lime, and about 20 per cent. of phosphate of lime, and as that could be got into Lossiemouth at 12s. a ton, and the carriage to the distillery would not be more than 2s., it would give them a material for about 14s. whereas they were paying 27s. or 28s. for ground lime, and it would fulfil the same function, as I thought. But to my great disgust and surprise, I found that the carbonic acid which was liberated during the boiling was carried on with the liquid to the evaporator, and that during the evaporation the carbonic acid was driven off and killed the flame in the flues.

26351. Have you anything to say about spraying of the trays in this process of evaporation?—Well, the spraying does seem efficient. The trays are so far efficient. I do think that if the pot ale was mixed with some lime before it went on to the trays, the evaporation would be quicker; they would get their paste sooner; that could be drawn the sooner, and then treated in the way that I have suggested with vitriol and phosphates, so that the expense could be lessened materially.

26352. Then there were some other points you were going to give evidence upon, but I will ask the Commissioners whether they have any questions to ask you upon this point of evaporation.

26353. (*Colonel Harding.*) I should like to ask Mr. Hunter what is his objection to complete incineration;

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is it a question simply of cost ?—Cost is one point If distillers are going to rely upon the by-product for profit, for lessening the expense, then the colour of a completely incinerated residue makes it almost prohibitive in the British market as a manure, and the nitrogen compounds would, to a great extent, be volatilized and lost.

26354. The colour ?—The colour. The black colour makes it almost prohibitive in Britain as a fertiliser.

26355. (*Chairman.*) Why ?—The dislike to the colour.

26356. It is black, is it not ?—Yes.

26357. (*Colonel Harding*). But do you think if it has good manurial properties the farmers would care what colour it is, red, blue or black ?—The farmers of Britain ?

26358. Yes ?—I am afraid that farmers would have a prejudice against it.

26359. Do you think if something is offered to them of high manurial value they will not have it because it is a black colour ?—The great majority of them will not touch it because of the colour.

26360. That you regard as prejudice ?—Greatly. I think there is some little reason for it, which of course ought to have been obliterated long ago. Many years ago there were black coloured manures put on the market which turned out practically worthless. I think that has something to do with it, but the fact is they will not have black coloured manures which are manufactured in this country. They are better suited for sugar-growing countries. That I know for an actual fact.

26361. Have you any personal experience of the process carried out at Dailuaine at the present time ?—Nothing but what I have been told.

26362. You have not seen their incineration result?—I have seen the product ; the material which they produce.

26363. And have you formed any opinion upon it ?—I know that it has been shown to a great many farmers in Scotland, and very few of them will touch it, in the Lowlands at all events.

26364. (*Chairman.*) Because it is black ?—Because it is black, yes.

26365. They can appreciate the quality of it from the analyses, but that will not guide them at all ?—Well, they do not rely altogether upon mere analyses, because those are very misleading very frequently.

26366. (*Colonel Harding.*) Do you happen to know whether as a fact they do not sell the whole of it at the present moment ?—I do not know, but I know it is not sold in the Lothians, or the Lowlands of Scotland. Great difficulty has been experienced.

26367. Do I gather that your only objection to that particular result is its colour ?—I have no objection whatever to the colour, but farmers are inclined to object.

26368. Apart from the farmer, the result seems a good one there, does it not; so far as doing away with the nuisance of pot ale in the streams it is a complete solution of the difficulty ?—As regards removing pollution from the streams undoubtedly it is a solution.

26369. Well, the great cost of it would depend entirely upon whether there is a permanent outlet for the product ? —Yes.

26370. You are disposed to think there will not be a permanent outlet because of the prejudice against the colour ?—Pardon me ; what I say is that if they were to alter their system, modify it a little bit in the way of altering the colour, the whole thing would go.

26371. (*Sir William Ramsay.*) The emanations from the chimney, I think, are not free from odour, are they ?—Oh no.

26372. Which may almost amount to a nuisance occasionally ?—There is no doubt of that.

26373. There has been no attempt to prevent that ?—I am not aware that there has been ; I think that could easily be overcome, just as they have overcome it at some destructors in the country. It is not necessarily a part of the evaporation process, but at Dailuaine they have added evaporation to my process. I should like to be very clear upon that point as regards this alteration of the evaporation process, the saving of cost by withdrawing the liquid sooner than incineration, and the mixing of it with a light-coloured phosphate and sulphuric acid. The by-products would be very much lighter in colour and I think that would overcome the prejudice that at present exists.

26374 (*Colonel Harding.*) Have you induced any distillery to try this ?—I have made the experiment at Dailuaine. I have made no attempt to induce any distillery to adopt anything, because I am too busy a man.

26375. (*Sir William Ramsay.*) As to the statement that the water from the evaporators if discharged into a stream would be an undoubted source of serious pollution, is it not simply distilled water ?—No.

26376. Has it a flavour ?—Most distinctly.

26377. Does it contain nitrogenous matter ?—It does.

26378. In the shape of ammonia ?—Not necessarily. There are other volatile matters which are certainly putrescible.

26379. Has it been proved that they are putrescible—such things as methylamine and other matters would not be putrescible ?—I have proved it myself.

26380. Is that so ? I should not have thought that volatile ammoniacal matters are putrescible ?—They are not all ammoniacal ; there are other products besides ammoniacal products volatilised.

26381. (*Chairman.*) Capable, if they meet putrefying organisms, of being putrefied ?—I have proved that, time after time.

26382. Did they not try your process at Dailuaine ?—It is at work, or was at work ; it is at work at Aberlour ; it is at work at Bulmenach.

26383. This work with the phosphates ?—No, not with the phosphates, because they have no incineration. At Aberlour they have no incineration except on a partial scale, and at Balmenach they have simply my boiling process, and then the liquid discharged goes to the bacteria beds.

26384. Perhaps you might describe your own process, if you will ?—The pot ale is run into a boiler direct from the still. Then I treat it with enough lime to overcome the acidity, and boil it thoroughly so as to get the acidity certainly overcome without having an excess of alkali, as an excess of alkali is objectionable in a stream. I take up any free alkali by adding a super-phosphate, and in that way I am increasing, of course, the value of the by-products. The liquid from that can go to a stream ; it is absolutely sterile, and of course without frothing. There is no danger whatever of becoming fungated, unless a long way down the stream, when steep waters may come into contact with it, but so far as I have made the experiment it has gone right to the sea without the slightest suggestion of fungation or of frothing.

26385. It is sterile, but it contains pabulum for organisms ?—Yes.

26386. If it meets with those it will give rise to changes ? —The phosphoric acid is practically all out, and you cannot have any fungoid growth without phosphoric acid. The method which was employed, of course, at Aberlour and Balmenach, and at Dailuaine, was, after boiling with lime as described, it settles, and quickly a clear liquor can be run to the bacteria beds and treated there, and if the beds are of sufficient area for the quantity of pot ale which is treated, then the water will go to the stream quite harmless.

26387. Your process was in use at Dailuaine, and has been given up in favour of complete incineration ?—Because the bacteria beds were not of sufficient extent to cope with the increased throughput which they had. The beds were put up to deal with a smaller quantity, which they were distilling two or three years ago, but they want to put through more, having an increased trade, and the bacteria beds of course were quite inadequate, consequently they had to do something more.

26388. At any rate they found that your process was too costly at Dailuaine ?—I do not know that they did.

26389 (*Colonel Harding.*) Just on this point of the beds, the beds you refer to at Dailuaine must have been at their best at that time ?—They were anything.

26390. The principle upon which they were worked was that the beds were first filled with liquid and then emptied after certain intervals ?—During all my visits

it was simply all run through—simply a filter. They were intended for contact beds.

26391. They were badly worked, but they were filled, were they not; they were not percolating beds?—During the most of the visits which I made to the place they were simply used as filter beds, clean run through.

26392. A stream?—Simply a stream.

26393. They were always full; the stuff came in at one end and ran out at the other?—Just so.

26394. Had you any experience of percolating beds—beds which were never full but which the water percolated through?—Yes, at other distilleries; but Dailuaine was not worked on that system—not while I was there, in connection with this boiling process.

26395. (*Chairman.*) You state that it is impossible to have fungus growth without phosphates. Has that been experimentally proved?—Well from my experience, if there is any growth at all it must be extremely limited.

26396. You have made observations, special observations upon that point?—Oh yes; it must be extremely limited.

26397. That is to say, you have used fluids without phosphates and sown in them a fungus and it will not grow?—If they grow at all it is extremely small.

26398. (*Sir William Ramsay.*) Would it not be more profitable, not to neutralise your pot ale with lime before evaporation?—Are you referring now to the evaporation process.

26399. I understand that you add lime, as a prelude to your process, and then you mix with sulphuric acid, and then you finally add a superphosphate. No, I beg your pardon; you first add sulphuric acid, do you not?—No.

26400. Then I have not understood your process. The first part of it was to evaporate with lime?—Not to evaporate; simply to boil and settle.

26401. (*Chairman.*) Reduce to an incinerated condition?—No, in my boiling process we take the stuff direct from the stills, treat that with lime; and then neutralise the alkalinity with superphosphate, and settle.

26402. (*Sir William Ramsay.*) Without any sulphuric acid whatever?—Certainly.

26403. Would it be possible to neutralise the acidity which is high in pot ale, to use phosphate and not superphosphate, and make superphosphate of the phosphate by virtue of the lactic acid in the pot ale; would that work?—Yes, in a way it would. That was the very experiment which I made—to use lactic acid to act on the phosphate of lime containing carbonate of lime, with the result that when they came to the evaporation, the carbonic acid which was liberated in the evaporation killed the flame in the flues and the evaporation stopped.

26404. Why should you wish to evaporate after that? You mean in order to dry it?—No, my own idea is, with that boiling process, if you have got bacteria beds of sufficient area for the quantity which is being put through, that bacteria treatment after the boiling is the method that ought to be followed.

26405. But we are talking of two different things. Surely, bacterial treatment would destroy the substance and make it absolutely valueless as a manure. I was supposing you were evaporating your pot ale, to begin with, to a certain consistency, and then adding phosphate, not superphosphate, but phosphate. It would surely solidify, and give you a manure which might be dried?—It might be dried artificially, but the advantage of using the sulphuric acid is that you form a sulphate of lime which takes the water up and becomes naturally a dry substance.

26406. But have you never tried with lactate of lime—will it give the same thing?—Oh, often.

26407. And it will not?—It does not.

26408. I should have thought there would have been no great difficulty. There is plenty of apparatus with which you could try the test?—Yes you can try it, but when you come to heat the superphosphate artificially it is no longer superphosphate. It will become insoluble; it will be regarded probably as a reverted phosphate, and have little more value than a purely insoluble phosphate.

26409. Quite so; I see that that would be an objection?—That, again, is bringing in the element of heating—the drying—and of course on the Spey side the cost of coal is very considerable, so that by using the sulphuric acid you get dried by the one process; you combine all the advantages by the one treatment.

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26410. To revert to the evaporation plan. I suppose your contention is that to calcine the substance requires more heat than can be furnished by the waste heat of the distilleries?—There is not enough heat from the distilleries to evaporate the whole of the pot ale. There are two objections to what they do at present. The first is to save the great expense of the cost of the last of the evaporation, and the second is that you will have less of the valuable stuff driven up the chimney, so that your product will be of considerably more value. At present in the incineration process it may have 1 per cent. of ammonia, it may have 8 or 10 per cent. depending on the amount of incineration; so if they could withdraw it before incineration is approached they might have a manurial body—that is a dried product with probably 8 per cent. of ammonia, and that is worth £4 16s. at the present market price. Any manurial body with nitrogen to that extent is worth at least 12s. per unit; that would be £4 16s. for the nitrogen alone, regardless of the phosphates, so that from that point of view it is certainly worth making the experiment. I would be quite willing to put £100 down in any distillery if they would do the like, to make the experiment. I do not want profit out of it; I would like to see the thing done, because I feel satisfied it would be of immense importance. With a little trouble, if it were once started it would become an everyday duty, and it really would become less trouble to them in the end.

26411. Would the waste heat from the ordinary stills be sufficient to evaporate the liquor to the state in which you wish it?—That I have never experimented with, but I rather think it would.

26412. Without purchasing coal?—Without extra coal, yes.

26413. (*Chairman.*) Then you speak of Anderson's process?—Yes.

26414. What is that?—There was a man brought some crystallised sulphate of lime to Anderson, and he was doing a lot of things with it. It was used for hardening brewing waters, and then he saw some notice of purification in distillery effluents; he thought he would try this stuff on it. He was totally ignorant of the *rationale* of the process. He found it did something, and they worked away with it until they got something of a result. The process is this. He mixed this crystallised calcium sulphate with peat, and filtered the pot ale through the mixture. Pot ale in going through this filter absorbs a considerable portion of the calcium sulphate, and comes through tolerably clear filtered through the peat and the calcium sulphate; then to the filtered liquid he adds caustic soda. His patent claims adding an alkali or lime or carbonates, but he does use caustic soda, and the result is——

26415. (*Sir William Ramsay*), I see you say that he has 60 grains of caustic alkali?—That is what I was looking for—yes, 60 grains of caustic alkali.

26416. (*Chairman.*) Is that used anywhere?—Yes it was used at one distillery, but I think they have given it up.

26417. (*Sir William Ramsay.*) May I ask where does the phosphate of lime come in; does he add phosphates afterwards to this liquid?—The phosphoric acid is in the pot-ale, the filtered pot ale. It contains nearly 140 grains to the gallon. That is the average of phosphoric acid per gallon.

26418. So he throws that down by the caustic alkali?—He forms phosphate of lime by the acid liquid passing through this filter.

26419. And then afterwards?—Then the phosphate of lime is only precipitated by rendering the solution alkaline.

26420. Afterwards; that is what I supposed. And then he uses sulphide of lime instead of ordinary lime?—Crystallised sulphide!—Oh no, not sulphide.

26421. It is a misprint; I could not make it out.

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26422. (*Chairman.*) Then you mention the Russell-Duncan process?—Yes, sir.

26423. That, you say, is a chemico-electrolytic process?—Yes, that is so.

26424. Could you describe in few words what it is?—Well, I think your experts were there the day that I was at Craigellachie; they know what the process is.

26425. You have nothing to say on this?—Nothing, beyond the fact that the gentleman has now left the district.

26426. Then you have something to say about the fermentation process?—Well, that of course is a process which has not been tried, except by myself and one of my old pupils, and of course on quite a laboratory scale—a little more than a laboratory scale.

26427. Is this using the pot-ale for the culture of yeast?—Yes, the percentage of acid in the pot-ale is of course too great for successful yeast culture, but by neutralising it by carbonate, or preferably by using slaked lime, it forms a very excellent medium on which to grow yeast, and we have grown practically every yeast which we in this country or Mr. Henson of Copenhagen have any knowledge of, and each of them was an entire success.

26428. But you will want a very small quantity of pot ale to produce all the yeast that was necessary?—It is not a question of making yeast; it is a question of using the pot ale, and if they take the nitrogenous putrescible matter out of the pot ale, the yeast can be very readily transformed into a manure by treating the refuse from the yeast culture which I have described, working up the residue from the evaporation process by making a manure. And yeast of course is nitrogenous, but then you see any extra yeast more than could be disposed of would be utilised in that way. It is also used at present in the making of feeding stuffs. It is used greatly amongst dried grains and other mixtures for cattle feeding, so it is not a question of only growing as much yeast as would be required for those distillers, but in working up the pot ale. Then as I suggest there is another valuable product; there is the spirit, as to which I do not know whether it might come in as a pot-still whisky or not, but it certainly looks as though it would be of great use for motor work.

26429. (*Colonel Harding.*) What would be the residuum from this fermentation of pot ale?—We could take it down to nothing, just as the distiller takes his work down to nothing.

26430. The residuum, such as it is, you would evaporate—incinerate?—Practically there would be none left in the water; it would be quite a small thing.

26431. (*Chairman.*) Surely there must be a good deal when you have grown the yeast in it for some time?—The distiller takes his wort down to zero; so could we do here, but the residuum could be quite easily treated.

26432. (*Sir William Ramsay.*) But the yeast sugar is not fermentable—I mean the pot ale sugar is not fermentable?—We are fermenting them—the sugars which are in the pot ale—with that treatment.

26433. There are two distinct questions here again. One is the using pot ale as a food to grow yeast—I dare say it might be good—phosphates and ammoniacal salts serve as food for yeast?—I beg pardon; there is not much ammoniacal salt.

26434. Well, nitrogen compounds which would serve as food for the yeast. Anyhow, you could use it as a pabulum for the making of yeast. It might be possible to sell that yeast and dispose of it in various ways. I presume you would continually get rid of pot ale on the same principle, not being able to sell grass, but being able to sell the sheep that feed on it. It is pretty much that. On the other hand, that is quite a different story, surely, from fermenting the sugars which are in the pot ale?—We do get fermentation.

26435. With yeast?—Most certainly, and we do get alcohol, and we have referred this subject to the Inland Revenue authorities; we have discussed the matter with them.

26436. Your first idea is to ferment the pot ale; but it has already been fermented, there is nothing but pentoses left; they will not ferment with yeast; whether there is another organism which will ferment them I do not know?—I do not know what change takes place in treating with the carbonates or with the alkali, but undoubtedly the fermentation is got. We get very rapid yeast growth, and certainly an alcohol produced.

26437. (*Chairman.*) There is evidence, is there not, of considerable amount of carbohydrate of some kind.

26438. (*Sir William Ramsay.*) They are all pentoses, and they will not ferment with yeast.

26439. (*Chairman.*) Are there not other forms which are not actually sugars?

26440. (*Sir William Ramsay.*) No, I think they are all pentoses.

26442. (*Sir William Ramsay.*) As they do not contain the right kind of carbohydrate they will not ferment with yeast. I do not mean to say they will not ferment with some other organism.

26443. (*Chairman.*) You appear to have overcome that difficulty with the pentoses?—We undoubtedly get very rapid yeast growth, and we certainly have distilled a spirit from the growth.

26444. (*Sir William Ramsay.*) Is it not possible that you have got a little of the hexoses left there in the pot ale, and you would get some spirit? Is it not possible that you have in the pot ale the constituents suitable for animal growth without fermentation to any great extent?—We might certainly have.

26445. (*Chairman.*) Can you grow yeast without fermentation?

26446. (*Sir William Ramsay.*) That is what I do not know.

26447. (*Dr. Houston.*) You can grow some forms of yeast with plaster of Paris only they multiply in a different way instead of the budding.

26448. (*Chairman.*) It is a very small growth.

26449. (*Dr. Houston.*) It is a feeble growth.

26450. (*Chairman.*) You have a luxuriant growth?—We have a luxuriant growth, and alcohol has been produced from every experiment made.

26451. (*Sir William Ramsay.*) You have examined the residual liquid?—Oh yes. If I had thought of it I could have brought the products here, because I have them.

26452. (*Chairman.*) Have you analysed the residual liquid?—I have not analysed it.

26453. You do not know what is left in it after you get your growth of yeast?—No, but I have treated it in the same way as I have suggested for the residuum from the evaporation by taking the thicker liquor and mixing it with strong acid, and then running in the phosphate and turning out a beautiful brown-coloured manure, the value of which would of course depend upon the class of phosphate used. The percentage of phosphate was from 30 to 40 per cent., and the ammonia or nitrogen equal in ammonia in the manfactured manure which included of course the sulphates of lime equal to 7 per cent. of ammonia.

26454. (*Chairman.*) Then you have experience of the use of pot ale thrown upon the land?—Yes.

26455. What have you to say with regard to that?—A large quantity of pot ale of course destroys herbage; the acidity is unfavourable.

26456. So will any manure if it is applied in too large quantities?—Yes, but the amount of acidity has much to do with it. There is no doubt that to a soil which has been recently limed the amount of ale which it can utilise or destroy is greatly increased, and is increased very much in proportion to the amount of lime which is used. Of course you cannot put on as much lime at once as would keep pot ale going for a month or a year, because the over alkalinity, on the other hand, destroys nitrification; so it would require to be periodically applied just as the ale was put on, probably from week to week in small quantities. But there is no doubt where lime is used, and carbonate of magnesia, the capacity of the soil for utilising pot ale is greatly increased, and is proportionate to the amount of lime which is used along with it, lime and carbonate of magnesia—one of magnesia to six of lime, that being the proportion which I find gives the maximum nitrification.

26457. The use of the pot ale would also depend on the nature of the land, would it not ?—Yes, very much.

26458. Are there lands for which it is suitable and lands for which it is not suitable ?—Yes. Heavy clay soil where filtration is slow and the aeration less than in a lighter soil, of course that is not so suitable for pot ale application.

26459. (*Colonel Harding.*) You say the applications of pot ale to land is apt to give rise to fungoid conditions ?—Yes.

26460. What do you quite mean by that ?—If the pot ale is mixed with steep water, that I think in all cases is the holder of the spores which give rise to the fungus.

26461. Your observation in regard to the treatment of pot ale on land does not apply where there is not mixed steep waters with the pot ale ?—That is so.

26462. Where the steep waters are kept separate your observation does not apply ?—My observation does not apply excepting that in the case where the pot ale is put on to such an extent that it may filter unaltered through the land by the drains into the river and be a source of pollution there. To that extent, of course, pot ale, if used alone on soil, is not subject to that objection.

26463. That would be of course excessive or careless treatment. Where pot ale is treated in a rational way on land of sufficient area, in not excessive quantities, you agree that that method of treatment is a practicable one ?—If the land is limed, certainly, but without lime it is apt to be come over-sour, bacterial growths are limited, and, of course, without bacterial growths agriculture is impossible.

26464. Have you had any opportunity of watching the contact of pot ale to land at the Glenlivet distillery ?—Not at the Glenlivet distillery.

26465. (*Chairman.*) Elsewhere ?—Yes.

26466. (*Sir William Ramsay.*) Have you any particular experience as regards putting steep water and yeast upon contact beds ?—Yes.

26467. Do you get purification ?—Oh, you get the opposite to purification. Purification does come into the question, but at the same time you get such rapid growth of the spores of the distillery fungus so-called; the growth of the fungus there is enormous, and there is no doubt whatever of the multiplication of the yeast, so they soon clog the beds and they become inoperative. That is why I regard their removal by the separate treatment of yeast—that is to say, the yeast, the washings from the vats and steep waters, a separate treatment for these two together—that is why I regard their separate treatment as being of the utmost importance in working contact beds.

26468. Do you think much harm would be done by running such liquors without the pot ale into the stream ?—Not if there is no pot ale going into the stream; I have found those spores, come from where they may. I have found some spores, for example, in the Carron at Dailuaine. I have got them a quarter of a mile above the distillery, the spores in the stream.

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26469. They do no harm ?—There was no growth there but they must have been coming from a growth above.

26470. (*Chairman.*) Is there any place above where they could have come from ?—I think there is a distillery above.

26471. (*Sir William Ramsay.*) But they did not cause the pot ale fungus in the stream—the presence of the spores ?—No, unless they took something to feed on.

26472. So that if pot a'e is kept out of the stream you can discharge the steep water without any serious danger ?—Yes, but of course if it comes down upon sewage you will have a fungus growing there as well, but it is quite easily kept out. I do not think there is any excuse for a distillery not keeping it out.

26473. Would you keep it out by putting it on land or through artificial filters ?—If they mix a steep water and spent lees together, and stir it with a little slaked lime, within an hour they will have absolute precipitation, and not a spore floating, and they can run that off to within a couple of inches of the level of the sediment, and if they work on the boiling process, or the evaporation process, they can pour this off with the ale. Then of course put it through either the boiling process or the evaporation process along with the pot ale.

26474. But that involves evaporating a very large amount of comparatively harmless liquor, does it not ?—It will only be the sludge they will evaporate.

26475. Oh, I beg your pardon, only the sludge ?—Only the sludge. Within an hour they will run off at least nine-tenths of the liquids in which there will not be a single spore. They have only one-tenth of the column to make hot. There is only the quantity at the bottom, which is extremely small, and if they conduct that sludge to the evaporator or the boilers, you have a very small addition to your volume and you keep your stream clear.

26476. What is the relative volume of the yeast washings and the spent lees ?—I cannot give you the figure, but the yeast washings are a very small thing.

26477. (*Chairman.*) I think I have asked you on all the points that are mentioned in your memorandum; is there any other point you would like to bring before the Commission ?—I do not remember anything.

EIGHTY-FOURTH DAY,

Tuesday, 23rd January, 1906.

PRESENT.

Sir Michael Foster, K.C.B., F.R.S. (*in the Chair*).
Major General Constantine Phipps Carey, C.B., R.E. | Sir William Ramsay, K.C.B., F.R.S.
Colonel T. W. Harding, J.P., D.L. | Mr. F. J. Willis (*Secretary*).

ALSO PRESENT.

Dr. A. C. Houston. | Mr. C. C. Frye.
Mr. George McGowan. | Mr. R. D. Littlefield.
Mr. G. B. Kershaw. |

Mr. James Burgess Readman, Doctor of Science, Fellow of the Royal Society of Edinburgh, called in; and Examined.

26478. (*Chairman.*) Mr. Readman, you are a Doctor of Science and a Fellow of the Royal Society of Edinburgh?—I am.

26479. And you practice as a consulting chemist in Edinburgh ?—I do.

26480. And on two separate occasions within the last seven years you received remits from the Court of Session in Edinburgh to examine and test the works and arrangements provided for the prevention of pollution by the discharges from two distilleries situated near the river Spey ?—I have.

26481. These pollutions may be classified into two large classes of pollution, the pot ale, and the other, refuse ?—That is so.

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26482. With regard to pot ale, there have been various methods of disposing of it; first of all, by putting it direct on land ?—Yes.

26483. What have you to say about that method, supposing that there is an adequate quantity of suitable land available ?—Well, if the land is porous, such as a loamy or sandy soil, it seems to do very well if it is not put on in excess; but I have seen the bad effects of it if it is put on in excess, even on porous, sandy soil.

26484. Any manure may be used to the detriment of land, may it not ?—It may.

26485. I mean, this is an agricultural problem, is it not ?—It is, quite.

26486. Has sufficient attention, do you think, been paid from the agricultural point of view, as to making the best possible use of this pot ale as manure ?—I think so; where the land is available it is taken advantage of.

26487. But with regard more especially to the way it should be applied and the times and the relative quantities ?—I am not sure that full attention has been given to this.

26488. Is it not possible that a good deal might be learned by a careful investigation ?—I think a good deal might be learned.

26489. So that a much larger quantity of pot ale than is at present used for land, even with the land available, might be used ?—It might be if the land was near, but it will not pay to carry it any distance.

26490. Of course, it must be land in the vicinity of the distillery ?—Of course, it ought to be near.

26491. Then the next process to which it may be subjected is that of incineration or combustion; that is, of exposing it to a very considerable heat ?—Exactly, but not incinerating.

26492. Well, not incinerating quite; it is reduced by a certain process—for instance at Tamdhu—to a black material ?—Still it contains a large proportion of nitrogen.

26493. I do not know quite what word one should use for it; it is not destruction ?—Torrefaction, I should say.

26494. Now, what have you to say with regard to this process ?—I think very well of it; I think that is the most reasonable way of disposing of it, as far as I know at present.

26495. That is carried to various degrees, is it not; for instance the Tamdhu material is reduced to a powder?—Yes, to a black ash.

26496. A black dry powder which can be conveyed readily to any distance at a relatively moderate cost ?—Yes, quite so.

26497. But in other places it is still more or less sticky, and far from being dry ?—Then it is not available as a manure.

26498. It is only the process carried to the extent to which it is carried at Tamdhu that meets with your approval ?—Yes.

26499. Can you make any statement with regard to the cost of that ?—Well, I do not think the Tamdhu method perhaps is the most economical, because it is entirely evaporation by steam, the multiple effect system; but where you may evaporate by the waste heat from the stills, I think it should be taken advantage of. I think the price for manure which you get would not pay the cost of evaporating it, but it would go a long way towards doing so; that is, taking the waste heat and utilizing it as far as possible.

26500. Yes, and that can be done ?—It is being done in several places; I can name them if you like.

26501. And that would reduce the coal bill ?—Oh, very materially.

26502. Would it reduce it so much as to bring it about that the sale of the material as manure would meet the cost of the process ?—I am afraid it would not.

26503. What proportion of loss would there be, roughly speaking; of course, you can only make an approximate statement ?—I should think it would take perhaps 40 per cent. more fuel than is available from the waste heat from the stills.

26504. What I rather want is, what would be the reduction on the total cost of the process ?—You mean the vaporation process ?

26505. Yes; you see if they threw the material straight into the stream it would cost them nothing ?—Yes, sir.

26506. It does cost them a considerable quantity to bring it down to the condition of saleable manure ?—I have a figure for it; I really do not recollect it at the moment.

26507. Could you supply the Commission with it ?—I think I could.

26508. (*Sir William Ramsay.*) You remember the cost of coal there which is about £1 a ton, I suppose ?—About £1 a ton.

26509. If it takes about 40 per cent. more coal to evaporate it do you know how many tons of manure could be produced per ton of coals; that would settle the question ?—I could not give that right off; I could supply it.

26510. (*Chairman.*) Dr. Readman could perhaps send us in later on the figure ?—Yes.*

26511. That would be equivalent to the real cost of the process to the owners ?—With the wear and tear of the plant and the labour attending it ?

26512. With the wear and tear of the plant and the labour ?—Three-fourths one evaporator claims.

26513. Three-fourths ?—Three-fourths; another claims two-thirds of the coal is saved by using the waste heat from the stills.

26514. The liquid in the pot ale; the water of this pot ale is by this process for the most part discharged into the atmosphere as vapour ?—By the chimney.

26515. A very small quantity is returned as condensing water ?—Oh, none is returned.

26516. None ?—Not by this system; not by the waste heat system.

26517. None ?—None at all.

26518. It all goes into the atmosphere as vapour ?—By the chimney with the smoke.

26519. That means that by this process a very large quantity of water is being removed from the adjoining stream and not returned ?—Oh, yes. It is not a very large quantity after all; I can give you the figures as to the quantity. It is not a very large quantity.

26520. Is it not a very considerable quantity ?—Well, it amounts to sixteen gallons per bushel. That is approximately the quantity of pot ale produced by a bushel of malt.

26521. Yes, but put it in this way; without treatment, the manufacturers, the distillers, return to the stream the same quantity of water that they take out ?—Yes.

26522. Now, they do not return anything because it all goes in vapour into the atmosphere ?—Yes, but the amount is only about 50,000 or 60,000 gallons a week in a big distillery; it is not a serious matter.

26523. Not when the stream is a relatively small stream? 60,000 gallons a week is not a large quantity.

26524. That you think is not a matter of importance ?—I do not think there is anything in it.

26525. Then there have been attempts to treat this pot ale in other ways ?—Yes.

26526. For instance, by a bacterial process ?—Yes.

26527. What is your experience of the bacterial process ?—I have only been an onlooker of course at all these processes, but any effluent I have seen from the bacteria beds has not been at all satisfactory.

26528. Do you know the bacterial bed which has been erected at Dufftown by Mr. Cowie ?—I have seen it at the first stages about three years ago.

26529. You have not seen them in their present condition ?—I do not know whether they have been altered since then.

26530. At present—I am speaking from memory—but I think I am right, Mr. Cowie first treats the crude pot ale with lime, by which he neutralizes it and also precipitates a considerable quantity of suspended matter, and then

* The figures referred to are given by Mr. R. R. Tatlock (*see* Question 26717).

he throws it upon a series, I think, of seven contact beds in succession, and finally puts his effluent through a percolating filter; then he claims in that way to have got an effluent which at all events is not altogether a bad one. The oxygen absorbed is 2·5 ?—Yes, I have seen it as low as that.

26531. Some of them, when one comes to look at the analyses, are lower than that; I mean it is an effluent which you cannot state to be definitely bad; in fact it is very nearly up to the Mersey and Irwell standard in that respect ?—I may say, Mr. Chairman, that in one of the samples I have received it has been as low as that; I did not know where it come from; the samples were sent to me; I did not take them myself; they were sent after I returned to Edinburgh, and I did find one as low as that and only one.

26532. (*Sir William Ramsay.*) Was that three years ago ?—No, not quite so much, two-and-a-half years ago, May, 1903.

26533. (*Secretary.*) When was that continuous filter of Mr. Cowie's made ?—(*Dr. McGowan.*) Was it not made at our suggestion ?

26534. I think it was.—I think it was after we had been up the first time; that would be about two and a half years ago.

26535. (*Chairman.*) Admitting that the other processes have failed to produce anything like a good effluent, this seems one in which a good effluent is at all events very nearly got ?—(*The Witness.*) I think it might be attained.

26536. Then turning to the other sources of pollution, the steep waters, and the wash waters, and the spent lees, they are on the whole of less importance than the pot ale ?—Very much.

26537. Do you think these can be discharged without any treatment at once into a stream ?—If the stream is big enough it can, I do not think it would do to discharge them into a small stream; they are bound to foul it sooner or later.

26538. I see you state, I have proved that the last three discharges are not injurious to fish life, by a series of experiments with young trout ?—That is so.

26539. Could you amplify that statement a little further ?—Might I read what we did ?

26540. Yes. These I understand are discharges without treatment ?—Without treatment, only the water used in steeping the barley in the process of malting was allowed to flow continuously through the tank containing the grain.

26541. Quite so; that gives you a less strong fluid ?—Very faintly coloured with organic matter.

26542. But still containing I mean a good deal of impurity ?—It does, but it is in a very much diluted form. It is rather a long statement. This is a report dated 3rd March to the Court of Session in Edinburgh.

> "Since submitting the Fourth Report, dated 6th January last, the distillery has been in constant work, but owing to the severe frost and snow, which occurred about the beginning of February, we thought it prudent to postpone our inspection which we had intended to make about that date.
>
> "Being desirous however, of testing at the earliest opportunity what, if any, effect the effluent from the distillery will have upon fish life, we have had a careful, and as we venture to think, an important, test or experiment carried out at latter end of January.
>
> "To do this we had about three feet in length of the wooden spouting which carries the discharge from the Distillery to the River Spey cut away, and into the gap we had placed a small wooden tank or box. This tank is about three feet long, two feet wide and had a depth of fifteen inches from the bottom to the outflow. On the bottom of the tank were laid two or three inches of sand and gravel with some large stones on the surface. Gratings were placed on the inflow and outflow to prevent the escape of fish. The tank is covered by a wooden lid and secured by patent padlock."

That was the entire effluent from the distillery except the pot ale.

26543. That was the steeps and the wash water ?—And any spent lees.

26544. Any spent lees as well ?—Yes.

26545. Just as they came from the distillery without further dilution ?—Without further dilution other than what has been stated in regard to the steeps water.

> "The whole undiluted effluent from the filter beds enters this tank at one end and flows out at the other. This tank having been fitted up as above described, Mr. Manners" —that is my colleague in this matter; he is a civil engineer in Inverness— "went to MacAllan distillery on Saturday, 27th January, and having seen all in order, placed within the tank two trout which he had procured that morning. He then locked the tank and gave the key to our representative, who was instructed to make daily examination, and report if either fish died during the week's trial proposed.
>
> "Up to Friday, 2nd February, he reported that he found both fish alive and well, but that on inspection on Saturday, 3rd February, he found one was dead and the other alive, and apparently in full and vigorous health; one had thus been fully six days in the effluent, and the other, the one alive, seven days.
>
> "On that day, 3rd February, the experiment was concluded." I think that is all I need read.

26546. Then these two fish lived entirely in that effluent? —Entirely in that effluent.

26547. And one lived for six days ?—And the other was alive on the seventh day.

26548. Then it is your opinion, Dr. Readman, that the whole of the steeps water, spent lees and washings, might be discharged into any stream ?—Not into any stream, but into the Spey certainly they can be.

26549. But you see these fish lived in the effluent itself without any further dilution ?—They did, but I think the river they are turned into would get foul, and covered with that peculiar fungus that appertains to this liquor sooner or later. I have seen it myself in small streams.

26550. And so indirectly injure the fish ?—I do not think it would injure the fish; it would disfigure the river.

26551. This is not a question on injuring the fish ?—No, I think not; I think it would not injure the fish.

26552. It would simply disfigure the river ?—Yes.

26553. It is said the fungus clogs their gills ?—It has been stated.

26554. (*Sir William Ramsay*). You have not any particulars ?—I have not any knowledge on the subject.

26555. The quantity produced, even in a small stream, would hardly be able to kill the fish by clogging their gills ?—It is wonderful how it grows. In the case of this distillery we have the whole effluent conveyed in wooden pipes straight to the Spey, and taken direct out into the Spey.

26556. (*Chairman.*) Is this fungus one fungus, or more than one species ?—It is one; I forget the name of it.

26557. Is it leptomyces ?—That is it.

26558. Have you paid any attention to the natural history of the fungus ?—No.

26559. You do not know of any accurate observations as to what are the conditions which determine the development ?—No.

26560. The spores I suppose were contained in the steep water ?—Yes.

26561. It is the spores that give rise to the fungus ?—In the burnt ale.

26562. Is it in the washings too, do you know ?—The washings are practically the same.

26563. A diluted pot ale, are they not ?—Yes.

26564. You do not know whether it comes chiefly from the barley or chiefly from the washings ?—I think it comes from the washings as much as anything.

26565. And you do not know the conditions which determine its development ?—I do not know.

26566. You do not know of any observations on that ? —I am not aware of any.

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26567. (*Sir William Ramsay*) I do not think a distinction is being drawn between two evaporation processes, one of which you spoke of as involving multiple distillation, and the other in which the pot ale is allowed to run in at the top of a flue up which the hot gases from the furnace are passing. These two processes are being carried on quite separately ?—Quite.

26568. Can you draw any distinction between them, and give the preference to one over another ?—There is a good deal of wear and tear in plant I should say in the case of the multiple evaporator. It will not do, I understand, to be made of iron. It must be made of copper, because there is lactic acid formed and that seems to attack all the metal parts unless they are made of copper.

26569. You think the running expense of that would be high ?—I am afraid of it, and it is a very expensive plant.

26570. The other, of course, has no such plant; it is a very simple affair ?—No. May I show you the system that you spoke of just now (*paper produced*).

26571. Yes, that is the second. The first, of course, will take less fuel than the second; the triple effect ?—Very much.

26572. The triple effect, rather than exposure to flue gases ?—Very much.

26573. Do you think the saving of cost on that fuel would pay for the upkeep of the plant ?—I do, yes.

26574. Then there is also a charring process which follows evaporation ?—They do char in that case in the lowest flue of all, after the solution has evaporated to a sticky consistence, the lowest flue being the hottest.

26575. In the case of the triple evaporation, the residue which is obtained is ready to evaporate in tanks over which flame is caused to pass ?—A separate process altogether; this is done in the same process, as I understand it does not require different apparatus.

26576. They then heat it to 600 degrees, and char it and sell the remainder as manure ?—Yes.

26577. Do you think much ammonia escapes during charring ?—Yes, a good deal, but there is 6 per cent. in the residue.

26578. And in the dried pot ale ?—6 per cent. of the residue is nitrogen.

26579. In the charred substance ?—In that charred substance.

26580. Would it be worth while attempting to recover the ammonia which escapes ?—I hardly think it would; there is so much heavy tarry vapours given off at the same time.

26581. The residue by the other method is not so good for manure; it is sticky ?—It will not do for manure, it is deliquescent.

26582. And nothing can be done with it except to bury it ?—Nothing.

26583. I suppose the yeast and the wash water come from casks which are washed out ?—The fermenting tuns, yes.

26584. Going back to one of your first statements as regards the application to land, I think you said there had been no serious systematic experiments carried on, but are you acquainted with any land to which pot ale has been applied for a long time ?—Yes, on MacAllan's distillery they dispose of it entirely in that way.

26585. And there is no deleterious effect on the land? —No, it is very carefully done there. It was the first distillery which had a serious law suit; they were interdicted, and I was appointed with a Mr. Manners to inspect and report to the Court actually what we saw there. The distiller uses the pot ale on his farm successfully along with its use in feeding cattle and gets rid of it entirely in that way and no other way.

26586. He has, of course, the advantage of possessing a farm ?—He has a good ground for it.

26587. Then where there is ground, do you think that is the most advantageous way of disposing of the refuse ? —It is the simplest way, undoubtedly.

26588. And not only of disposing of the refuse, but of improving the soil, I suppose ?—Yes, he gets a very much improved crop.

26589. One hears that the pot ale burns the crop ?—In quantity it does; if put in excess.

26590. But that is easily avoided, I suppose?—Quite.

26591. We have been told that the manure produced in this way does not sell, because it has a black colour, the farmers being prejudiced against any manure of a black colour ?—I hardly think it would sell alone; I think it might be necessary to mix it with a superphosphate.

26592. So as to change the colour ?—It would.

26593 (*Chairman.*) There is very little potash ?—Very little pot ash, very little indeed. You will see the analysis, I think, in the red book.

26594. But is it true that the farmer in Scotland has a prejudice against black artificial manure ?—I should think he has; I am not quite aware of it, but I should think he has.

26595. (*Sir William Ramsay.*) Well, there is from 8 to 10 per cent. of phosphate, and from 1 to 2 per cent. of potash, and from 3 to 8 per cent. of nitrogen. We have been told of another process which is suggested, and that is to mix the evaporated pot ale with a certain amount of sulphuric acid, and then to neutralise with phosphate of lime containing a great deal of carbonate, the effect of which is said to form gypsum from the sulphuric acid and the lime, which takes up the water of the nearly dry syrupy pot ale and so makes a solid manure consisting largely of superphosphate, sulphate of lime, and the constituents of the pot ale. Are you aware of that plan having been tried ?—I am not aware, but I should doubt if it would be quite solid and not deliquescent. There is only half a pound of solid matter in the gallon.

26596. But this is after evaporation ?—Yes, after.

26597. After it has been made into a syrup. That looks a reasonable process, do you not think ?—Still it involves evaporation.

26598. Involves evaporation, but it adds to the pot ale a valuable manure in the shape of phosphate, and the process might solve the question of making a marketable manure ?—I think it is rather complicating the issue.

26599. It really is establishing a manure manufactory ? —Yes.

26600. Do you think it is not a sufficiently large problem to go to expense of that kind ?—It is surprising how very little there is altogether in a large work: I mean the total solids from the burnt ale are not very large.

26601. Then there is another possibility, that is collecting all the material to some central station; establish a manure work there and so dispose of it; is that conceivable ?—The cost of carriage is so great.

26602. It might be run by pipes ?—The distillers, as a rule, are not near enough together; they are pretty well scattered.

26603. You mentioned some particular district where filtration was tried through a gravelly soil with disastrous results ?—I think I have heard of that case before; too much was put on and the whole soil grew foul. This was a case, as I understand it, of an old quarry—I saw it in the distance—into which the whole of the burnt ale was pumped; it had a gravelly bottom and the burnt ale did not appear in the stream for two years; it had two years to filter. The moment it touched the stream a thick carpet of fungus was formed and the stream finally discharged into the Spey or some of the big rivers adjoining.

26604. (*Chairman.*) That was an attempt to use the land, to use the quarry simply as a bed ?—It appeared at the end of two years, and can be seen yet very distinctly.

26605. So that filtration through a very great thickness of soil does not seem to destroy it ?—No use whatever.

26606. It has been stated that the growth of this fungus is due to phosphate; if the phosphate was removed the fungus would not grow. Can you confirm that by any information you have on the subject ?—That is a possibility; I am not aware of that; I am not aware of the history of the fungus nor read any of it; I think that is quite possible.

26607. It would not be so difficult to remove phosphates from the pot ale ?—It would not be very easily done.

26608. And leave the rest. As regards the steep water and the wash water; the steep water is applied in one or two ways, first, allowing it to stand over the grain; second, applying it as a current running over the grain. I suppose the latter takes a very much larger amount of water than the former ?—Very much; I can give you figures; the one is about 11 gallons per bushel—that is where it is allowed to stand on the grain; and the other is 140 gallons per bushel.

26609. (*Chairman.*) The same total of impurity is removed ?—Yes, in both cases.

26610. (*Sir William Ramsay.*) In the case of the fish, which did they live in; the 11 gallons or the 140 ?—No, the 140.

26611. Is it worth while putting such wash waters through bacteria beds ?—I think it would be in the case of a small stream; where the discharge is run first into a small stream, for the sake of the stream, for the appearance of that stream; in this case I would not recommend the flow through system; I would minimise the water as much as possible.

26612. (*Major General Carey.*) In the absence of suitable land for the treatment of pot ale, do you consider that evaporation is the only alternative and practical method of disposal which will give satisfactory results ?—So far, I think so.

26613. Have you any specific information as to the manurial value of the residue which has been obtained after evaporation ?—I believe about 9s. to 10s. a unit of ammonia is the value of it, 9s. to 10s. That is to say, 6 per cent. would be £3 a ton.

26614. Is there a ready sale for that product ?—I really am not sure; I should think so. Ammonia is a standard article, and anything containing nitrogen has got a standard price and is readily sold at that figure.

26615. That cost would pay to a great extent the cost of evaporation —I think so.

26616. (*Chairman.*) In your fish experiment the fluid in which the fish lived in the tank was not the raw material, the raw steep water; it had been treated ?—No, not treated in any way; only steep is diluted by letting the water flow continually through rather than allow the water to remain at rest on the grain.

26617. (*The Secretary.*) There was no filtered liquid in it as well ?—It was all filtered through sand filters.

26618. (*Chairman.*) It was filtered through sand filters ?—Yes, everything was filtered through sand filters first.

26619. First ?—It was all run into one tank first of all and then passed through sand filters.

26620. What kind of a sand filter was it ?—Gravel and sand on top.

26621. What depth ?—2 feet 6 inches, I think it was, inside.

26622. One filter ?—One filter, yes; with a second ready to be used when the first got fouled or wanted a rest.

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26623. How did it pass through the filter ?—Rapidly with a 4 inch discharge pipe at the bottom.

26624. A continuous filter, was it ?—Continuous filter. We first received the whole discharges of the distillery, except burnt ale, in a large cement tank above the filter, and below was the filter into which the tank was discharged.

26625. There was precipitation in the tank ?—No precipitation; there was a little sediment, grain, and so forth deposited, but very little, very trifling.

26626. And then it passed continuously through this gravel and fine sand ?—Yes, without any check whatever; no tap of any kind to check it.

26627. Did you analyse at all the effluent from that sand ?—Very frequently.

26628. What was its character. This was the effluent to which the fish were exposed ?—Yes. The analysis of the outflow to the Spey—

	Grains per Imperial Gallon.
Total solids	30·13 grs.
Comprising—	
Suspended, insoluble	·28 grs.
Volatile in solution	11·30 ,,
Saline, etc.	18·55 ,,

N.B.—There was no suspended matter when samples were drawn.

Free or saline ammonia	·033 grs.
Albuminoid ammonia	·269 ,,

Nitrogen as nitrates and nitrites, sometimes present in traces.

Chlorine	2·85 grs.
Oxygen absorbed	2·270 ,,

Reaction—varies from faintly acid to slightly alkaline on standing.

Colour—straw yellow.

Appearance—clear bright at first but cloudy later.

Odour—faint earthy at times.

26629. There was considerable purification then over the crude material, was there not ?—Not much; if you take into consideration the dilution there was really not very much. I think that table perhaps might be worth your attention. That gives the whole discharges into the Spey.

26630. You will put that in; may we take that as part of your evidence, this table ?—I think so.

26631. And print it ?—I think so.

26632. Are you able to state anything as to the comparative cost of the torrefaction method with the successful artificial filtration method such as that carried out by Dr. Cowie at Dufftown ?—To compare the one with the other ?

26633. Yes ?—I am afraid I cannot, but I would give it you if you would give me a little time to consider it.

Mr. Robert Rattray Tatlock, called in; and Examined.

26634. (*Chairman.*) You are a Fellow of the Royal Society of Edinburgh, and of the Chemical Society of London, and of the Institute of Chemistry of Great Britain and Ireland ?—I am, sir.

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26635. And you have paid very considerable attention to the refuse from the whisky distilleries ?—Yes, sir.

26636. You have been kind enough to send to the Commission a paper, which we have printed, and now bears some corrections of yours ?—Yes, sir.

26637. Will you put this in for printing by the Commission as it is ?—Yes, sir, with corrections, if you please.

Paper Submitted by Mr. Robert Rattray Tatlock.

I am an analytical and consulting chemist and have been in business in Glasgow in that capacity for the last thirty-five years.

I am one of the public analysts for the city of Glasgow, and have held that appointment for the last thirty years and I was sewage chemist to the Corporation of that city for six years.

I am a Fellow of the Institute of Chemistry of Great Britain and Ireland, of the Royal Society of Edinburgh and of the Chemical Society of London.

I was formerly Examiner in Chemistry at the University of Glasgow.

In the ordinary course of my business I have had much to do with sewage matters and with the treatment of manufacturers' liquid refuse.

Many years ago I experimented with the "spent wash" or "potale" of distilleries, in the hope of finding some method of treatment which would render it fit to be turned into watercourses, but entirely without success.

As illustrating the utter hopelessness of finding a process of treatment that would save distillers from the costly litigation that had been going on and that was still in prospect, the following may be quoted:—

"Wine Trade Review," vol. XXXVIII., No. 425, for

Mr. Robert Rattray Tatlock.

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September 15th, 1898, page 647 (Editorial, entitled "Distillers and the Pollution of Streams"), in which, after stating the adverse result in the Kemp and Macallan case, the following occurs :—"They (the distillers) have manfully tackled the subject, and endeavoured in various ways to remove all possible causes of complaint. So far they have been unsuccessful, but they are persevering with experiments, and twenty-one of them have combined for the purpose of offering a premium of £2,000 for the discovery of a method which shall be really efficaceous."

It is a significant fact that although this premium was offered by advertisement, both in this country and on the Continent of Europe, no one ever applied for it, or even submitted a process.

In the same number of this journal, page 677, there is published in full, a report by Vivian B. Lewes, Professor of Chemistry, at the Royal Naval College, Greenwich, to the North of Scotland Malt Distillers' Association, on the subject of Distillery Pollution, in which the following appears :—

"In all, I have made over 100 experiments, with every precipitant or combination of precipitants which are likely to offer any chance of success, and found that heavy liming was the only thing which showed any considerable precipitation of the dissolved solids, it being possible, by this means, to reduce them from 2·54 to 1·4 per cent.; but the cost would be prohibitive, whilst the effluent would still retain the property of frothing, and I am of opinion that any such process offers no chance of success.

"I am strengthened in this opinion by inquiries made on the Continent, from which I find that a similar effluent caused great trouble to the dextrine manufacturers in Germany and Belgium, owing to the fouling, caused by vegetable growths in the stream into which the waste water was run, and that a very high premium was offered for a treatment which would reduce or do away with it; but in spite of many German chemists devoting years of labour to the question, it still remains unsolved.

"The last method by which it might be possible to deal with it would be by evaporating down to a solid, which could then be dealt with; and at first sight it seems feasible to do this, by utilising the waste heat in the flues for the evaporation of the spent ale. On a small scale this could undoubtedly be done, but it must be remembered that at Dailuaine the production of potale is 63,000 gallons a week, and I fear that the waste heat in the flues would only be able to evaporate a small portion of this volume, and that its evaporation would probably entail the erection of a large plant and the consumption of a considerable amount of extra fuel, whilst the viscid nature of the residue, as it approaches dryness, would give rise to trouble in keeping the apparatus in working order.

"I am, therefore, of opinion that although this solution of the problem appears at first sight a tempting one, and is well worth a trial, yet in practice it is quite likely that it would not be found possible; and I am strongly of opinion that in the interests both of the riparian proprietors and the distillery owners, the best method of dealing with the burnt ale is to run it straight out of the still, whilst hot, through filters, in order to keep back the solid material, which would render the stream turbid, and then to discharge the filtrate, diluted to the greatest extent that the water resources of the works will allow, by a pipe leading direct into the middle of the stream. If treated in this way excessive dilution will retard any fermentation changes for a very considerable period, and the burnt liquor, being sweet and fresh, will rather form a valuable food for the fish, than a source of pollution; and the flow of the stream and further dilution will, in all probability, be found to do away with, or reduce to a minimum, the trouble which is at present caused when the liquid is allowed either to infilter through the banks or to slowly enter through ditches and brooks.

"Should, however, the riparian proprietors decline to allow this, and should the evaporation to dryness prove a failure, I am afraid a discharge pipe to the sea will be the only solution to the difficulty."

Such was the state of general knowledge among experts in 1898.

Further, in the "Banffshire Journal" of February 28th, 1899, there appeared a report of proceedings which had then taken place in the Banff Sheriff Court, before Sheriff Grant, in an action, at the instance of Messrs. George Cowie & Sons, Mortlach Distillery, and Alexander Mitchell Cowie, against the Burgh Commissioners of Dufftown to have them ordained to allow the pursuers to discharge the refuse of the distillery direct into the burgh sewer. In that account of the trial the evidence of Dr. Stevenson Macadam, of Edinburgh, is reported in the following terms :—

"Methods that were adequate for ordinary sewage would entirely fail to deal with burnt ale in the crude state, or with burnt ale mixed with such quantities of sewage as they had to deal with in Dufftown.

"He had diluted it experimentally and treated it with lime and alum, but he could not rid it of its noxious matter.

"Dr. Macadam entered at length into other analyses he had made, and said he knew of no chemical process that would satisfactorily purify burnt ale."

In the same account, C.E. Doig, C.E. Elgin, was reported as follows :—

"He had had a scheme of evaporation, and had taken out a patent for it, but now there were many better schemes. He considered the price offered by the distillers, for a good method of disposal, a very poor one."

In the "Aberdeen Journal" of Saturday, August 4th, 1900, there appeared a Report of the proceedings at a Sanitary Congress held then in Aberdeen, at which James Hendrick (now chemist to the Highland and Agricultural Society) read a paper on the "Composition and Disposal of the Refuse from Whisky Distilleries." The following occurs in this report :—

"An attempt to deal with the matter by filter beds turned out a complete failure, and only increased the nuisance. They proved receptacles in which the highly putrescible liquids were able to undergo anœrobic decay in a mass, and produced stinking ponds of putrid organic matters, which soaked through the ground to the nearest river course and caused ugly green masses to take the place of the healthy green growths of a clean river. Burnt ale was the cause of the pollution.

"It was a wholesome substance when fresh, but the feeding value for cattle was not sufficient to induce farmers to go to much trouble to relieve distilleries of it. It was practically impossible to prepare, by evaporation, a dry, marketable product like burnt ale. When a certain stage of concentration was reached it became a thick, gluey, untractable substance which would be difficult to dry further. The fatal objection to such a syrup for cattle food was its great acidity."

"In the *Journal of the Society of Chemical Industry*, Vol. xx., No. 5, 31st May, 1901, a paper is published which was read at a meeting of the society on the 30th of the previous month, also by James Hendrick, entitled "Composition and Disposal of Burnt Ale and other waste liquids of Whisky Distilleries." In this paper the following passages occur :—

"Burnt ale cannot be obtained as a dry solid by evaporation. When evaporated down it becomes a thick, dark, sticky mass, which would be very difficult to deal with in any evaporating plant. Even prolonged heating in a steam oven only reduced it to a plastic material, which is very tenacious."

"Unfortunately, however, even if we could concentrate burnt ale to this extent, the concentrated material would be unsaleable on account of its untractable condition. It could not be ground and dried into a sowable condition. Even if mixed with a large bulk of other materials it would render them sticky. I attempted to get over this difficulty by rendering the burnt ale slightly alkaline with lime before evaporation. This improves it a little. It could be dried, though with difficulty, and could be powdered while still warm. But the powder if left exposed to the air soon falls back, even in dry weather, into a viscid condition, in which it could not be marketable as a manure."

This was the state of knowledge on the part of the best authorities in 1901, but as far back as 1897, my attention was directed by Messrs. Robert McAlley and Thomas Storer to a process which they had devised for producing a valuable manurial product from potale, and to its hitherto unsuspected value as regards richness

in available nitrogen, potash and phosphoric acid. They succeeded in doing what all their predecessors had despaired of doing, namely, to produce a rich and valuable natural manure in a fine condition for sowing, and remaining so under all conditions of transit, storage and use. Much patient investigation was required, however, before a successful issue was reached. In December, 1897, I analysed the products of their small scale experiments, and in September, 1899, they erected a plant in Glasgow, and made a demonstration with 550 gallons of potale brought from Tamdhu Distillery for the purpose. This was entirely successful, and resulted in their applying for and obtaining Letters Patent, which are respectively No. 6348 of 1899 and No. 9514 of 1901. In the meantime the Highland Distilleries Co. had erected a temporary plant at Tamdhu to test the process on a large scale, again the success of the process was placed beyond a doubt, and this company acquired the right to use these patents at Tamdhu Distillery This plant consisted of open evaporating tanks and drying pans, but the result of the demonstrations with it justified the erection of a quintuple effet evaporating plant, with an arrangement for drying the residue, obtained by evaporation, by the heat of the flue gases. These inventors made the all-important discovery that the product, if heated to a uniform temperature of about 320° F. permanently lost its viscid and sticky quality, was friable, and when ground did not become sticky again in a damp atmosphere, but remained in the form of a powder, ready for sowing at any time. This was a great step in advance. The new plant has now been in operation for a considerable time and has satisfied the most sanguine expectations. The product is a manure of the highest class, having its constituents more thoroughly incorporated than they could possibly be in a mixed manure. I hand in a statement (A) of the composition, as found by analysis, of the potale from which the manure is made, also a statement (B) of the average product obtained, and of its value, on the basis of the valuations issued by the Highland and Agricultural Society. I also present a statement (C) of the approximate costs incurred in the recovery of the product, for comparison, no waste heat from the distilling process being utilised. It will be seen from these that the application of the process does not involve much current cost, the price obtained for the product covering nearly all outlays.

It should be observed that all these figures apply to malt (pot still) distilleries only, which lend themselves to its adoption more readily than grain (patent still) distilleries, as, in the former, worts are set, to ferment, at a somewhat higher gravity than in the latter, thus giving a rather more concentrated potale. Also in the former a considerable quantity of water is evaporated with the spirit in the wash still which still further condenses the potale, while in the latter but little water is evaporated with the spirit, so that practically no concentration of the potale takes place. The question whether the process can be applied in the case of grain distilleries without incurring any current cost, will depend on the strength and composition of their potale, but considering that most malt distilleries, being distant from coal-producing centres, are heavily handicapped by railway carriage for their coal, amounting in many cases to about 9s. per ton, the latter item is in favour of the grain distilleries, and will go a long way to neutralise the disadvantage of the weaker potale.

I am not prepared to criticise any of the numerous other processes that have been put forward, but I am strongly of opinion that, unless a process gives a bye-product whose value will neutralise costs, or nearly so, and if it turns into a water-course anything that does not approximate to distilled water in character, it is at a great disadvantage, and this process is free from objection as regards both these points.

I have also given attention to the polluting qualities of the other waste liquids from distilleries, namely, the "barley steep," the "washings," and the "spent lees," taking into account the composition of these, as well as the proportions in which they are discharged in relation to that of the potale. The observations as regards potale, however, were not made on the identical potale of which my analysis is given in Statement A, and consequently the figures are slightly different. I have found that these liquids are discharged in something like the following proportions :—

Potale - - - -	21,000 gallons.
Barley steep - - - -	1,2000 ,,
Washings - - - -	6,500 ,,
Spent lees - - - -	6,500 ,,

An analysis of each of these gave the following results :—

	Grains per gallon of Liquor.			
	Potale.	Barley Steep.	Washings.	Spent Lees.
Suspended Matter - - - - - -	362·5	9·5	12·4	None
Dissolved Matter.				
Organic Matter - - - - - - -	1,942·2	216·3	265·2	2·7
Mineral Matter - - - - - - -	406·7	127·0	44·6	4·1
TOTAL - - - - - -	2,711·4	352·8	322·2	6·8
TOTAL ORGANIC MATTER -	2,304·7	225·8	277·6	2·7

The whole of the suspended matter was regarded as organic matter.

The mineral matter has no polluting quality, only the organic matter, and therefore the latter only was taken into account in determining the relative polluting values.

If these four liquids were discharged into a water-course in equal volumes, say 21,000 gallons each, the following would be their respective polluting values, taking the potale at 100 :—

Potale.	Barley Steep.	Washings.	Spent Lees.
100	·10	12	·10

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But as the liquors are not discharged in equal volumes, but in the aforesaid proportions, their real polluting values relative to each other, based upon the total organic matter they respectively contain, will be as follows:—

Potale.	Barley Steep.	Washings.	Spent Lees.
100	5½	3½	·02

So that the *collective* polluting value of the last three is 9 against potale 100, or about $\frac{1}{11}$th.

It may, therefore, be fairly concluded that if these three liquors, the "barley steep," the "washings" and the "spent lees," be judiciously discharged, uniformly, into a water-course carrying even a comparatively small volume of water, their effect on the latter would be free from objection. It will be observed that the only liquid discharged from the distillery is the distilled water from the quintuple effet evaporators. I have examined this and have found it to contain only ·3 grain of total solid matter per gallon.

(*Signed.*) ROBERT RATTRAY TATLOCK.

STATEMENT A.

COMPOSITION OF THE POTALE RECOVERED AT TAMDHU DISTILLERY, SPEYSIDE.

Specific gravity	1·015
Equal to degrees of twaddell	3
In Suspension.	Grains per gallon.
Organic matter	326·5
Mineral matter	51·0
Total solid matter	377·5
Containing nitrogen	33·2
„ phosphoric anhydride	20·3
„ (equal to tribasic phosphate of lime)	44·3
In Solution.	
Organic matter	2,201·8
Mineral matter	245·0
Total solid matter	2,446·8
Containing nitrogen	154·1
„ phosphoric anhydride	82·5
„ (equal to tribasic phosphate of lime)	180·1
„ potash	103·7
„ free acid, calculated as lactic	491·5
TOTAL.	
Organic matter	2,528·3
Mineral matter	296·0
Total solid matter	2,824·3
Containing nitrogen	187·3
„ phosphoric anhydride	102·8
„ (equal to tribasic phosphate of lime)	224·4
„ potash	103·7
„ free acid, calculated as lactic	491·5

(*Signed*) ROBERT RATTRAY TATLOCK.

STATEMENT B.

Showing the Composition (average) of the Potale Manure produced at Tamdhu Distillery, Speyside, and Valuation, as per Highland and Agricultural Society's Scale.

	Per Cent.
Nitrogen	5·85
Equal to Ammonia	7·10
Phosphoric Anhydride	5·62
Equal to Tribasic Phosphate of Lime	12·28
Potash	4·58

Value, £5 5s. 5d. per ton of 20 cwts.

This Valuation is based on the following Unit Values :—

	£ s. d.
Ammonia, per unit per ton	0 10 0
Tribasic Phosphate of Lime	0 1 6
Potash	0 3 6

(*Signed*) ROBERT RATTRAY TATLOCK.

STATEMENT C.

Showing the costs incurred in converting Potale into Marketable Manure, at Tamdhu Distillery, Speyside based on the treatment of 21,000 gallons of Potale in one week—the bye-product of 1,500 bushels of Malt.

	£ s. d.
Coal, 7 tons 7 cwts. at 16s. 9d. per ton, delivered	6 3 0
Labour, 5 men at £1 2s. per week each	5 10 0
Bags	0 9 4
Sundries	0 8 0
Tear, Wear, and Depreciation of Plant costing £2,000 (at the rate of 5 per cent. for 52 weeks) for 40 working weeks in the year, for one week	1 15 6
	14 5 10
Produce, 2 tons 6 cwts., at £5 5s. 5d. per ton of 20 cwts.	12 2 4
This is for the product in bags, and shows a balance on the loss side, on the week's working, of	2 3 6

26638. Refuse from distilleries may be divided into two classes, the burnt ale or pot ale on the one hand, and the steep water, spent lees, and wash water, on the other ?—Yes, sir.

26639. Shall we speak of the burnt ale, first ?—Thank you, sir.

26640. That can be used by being put upon the land ?—Yes, it has been so used, sir.

26641. Have you anything to state to the Commission about that method which has been in certain cases quite successful ?—Yes, if too much is not used.

26642. That is, if an adequate quantity of suitable land is available in the immediate neighbourhood of the distillery, and the application is made properly, a very large quantity of the burnt ale may be disposed of in that way ?—Yes, sir, the land takes up a certain amount.

26643. But in certain other cases land treatment is not available ?—That is so, sir.

26644. Then the other methods which have been used are in the first place what perhaps we may speak of as torrefaction method where the burnt ale is reduced in certain cases to a dry powder which can be easily carted away ?—Yes, sir.

26645. What have you to say about that process ?—If that process is properly conducted and the product is carefully made, I think it is an excellent process.

26646. The process, I gather, may be badly conducted ?—Yes, sir, it may be burnt or it may be underdone, and the product then will not be marketable.

26647. Are there any very great difficulties in carrying out the process properly ?—I think not, sir, if the proper plant is used.

26648. Now, in that process the whole of the water and the potale is evaporated into atmosphere ?—Yes, sir.

26649. So that the water which is removed from the adjoining stream by the manufacturer for his process is not returned to the stream ?—Yes, sir, it is returned in the form of condensed water.

26650. But what proportion of the total appears as condensed water ; a very minute portion, is it not ?—No, sir, I should think that 95 per cent. at least is returned.

26651. (*Sir William Ramsay.*) May I just suggest there is a possibility of confusion. When you speak of torrefaction you are thinking of evaporation and torrefaction afterwards : is that so ?—Yes.

26652. (*Chairman.*) We are speaking of the whole process.

26653. (*Sir William Ramsay.*) There are two ways of doing it. The first is distillation by multiple effect, and the second, torrefaction. Consequently, torrefaction from the beginning, running the potale down hot chambers ?—Open chambers.

26654. (*Chairman.*) Such as is carried on at Tamdhu. Let us take the process at Tamdhu. Could you describe briefly again to refresh our memories about the process at Tamdhu ?—The process at Tamdhu is by evaporation in a multiple effect, and nearly the whole of the water is returned in the form of condensed water to the stream, and the product appears at that stage in the form of a thick syrup containing very little water, and that is torrified by exposure to heat in the flues.

26655. Then there is relatively little loss of water ?—Quite so.

26656. Certain vapours come off in doing the process of torrefaction ; are they likely to be a nuisance at all ?—Well, I have not observed anything more than a slight smell. I have heard that complaints have been made, but I believe that is all over, and nobody has any complaint to make now. That arises from the burning of the material, and it is entirely against the interests of the distillers to burn the material, because the valuable ammonia is dissipated if it is burned. At first, of course, that was inevitable.

26657. May we say then that if the process is adequately carried on there will be no nuisance in the vapours from the chimneys ?—I believe that is the case, sir.

26658. Then other methods of disposing of this potale are by filters and the bacterial method ?—Yes, sir.

26659. The simple filtration methods have invariably proved ineffective, I believe ?—I believe so, quite ineffective.

26660. Have any of the bacterial methods proved in effective ?—I really cannot say. I am aware of one

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being tried on the Spey—I have not seen the results of it—at Mortlach Distillery. I have not seen the results and I am not able to criticise any other process except that at Tamdhu, and now at the four distilleries at Rothes treatment works; I have seen some of them.

26661. At the one at Mortlach the potale is first treated with lime and precipitated. It is then thrown on to a series of contact beds and finally on to a percolating filter, and by that means an effluent can be obtained, which even at present I mean cannot be called a bad one; it very nearly reaches the Mersey and Irwell standard?—Quite so; I have not seen the effluent.

26662. Can you give the Commission any statement as to the comparative cost of the evaporation and torrefaction method as compared with the filtration method?—Not as compared with the filtration method. I know the actual cost of the torrefaction method, but the others I cannot give any details about with regard to cost.

26663. And the cost of the torrefacton method, what can you say about that: about the whole process?—Well, it was thought at first that it actually covered—

26664. You utilise the waste heat from the stills?—Not at Tamdhu. The only ground available at Tamdhu for putting down the treatment works was so far away from the stills and the flues that the waste heat could not be utilised. If it could there would be a great advantage from the results at Tamdhu.

26665. But still, with that disadvantage of not being able to utilise the waste heat of the stills, what is the cost of the process?—The price obtained from the manure very nearly covers all outlays, and it is expected that it will completely cover them as the process comes on.

26666. May we infer, then, that you are of opinion that where the waste heat can be utilised the cost would be more than covered?—I think so, sir. They are at a great disadvantage at Tamdhu with regard to not being able to use the waste heat of the stills.

26667. Then turn to the other refuse, the steep waters, and the wash waters and the spent lees. They are relatively small compared with the potale?—They are relatively small compared with potale.

26668. Do you think they can be discharged into streams without any treatment whatever?—I think, if it were properly done, it would be a pity even to filter them. The worst of them is the barley steep which varies very considerably according to the kind of barley being used at the time; it is the worst, but the objection to the filtering is really that whenever you begin filtration you cannot avoid producing disagreeable odours in the vicinity of the filter beds. It soaks through the soil more or less and begins to putrefy and decompose, and if it could be got rid of suitably by carrying it into the bed of the stream uniformly during the twenty-four hours I do not think on the Spey there can be any objection.

26669. You do not think they would give rise to a fungus in the stream?—I do not think so if it was done in that way, but to let it off all at once I think is not good.

26670. You think that in any distillery, if all these wastes were collected and held so that they could be discharged uniformly into the stream, that might be done without any ill effect whatever?—I think so, sir. It would involve storage tanks to let it off uniformly during the day and night.

26671. Would there be any putrefaction taking place in these storage tanks?—Not for the twenty-four hours.

26672. Do you think the riparian owners would be content with that?—I really cannot say, sir. I think at one time if they thought that the successful treatment of the pot ale was in prospect they would have been content, but now that that is achieved they may look for something more.

26673. Do you know the steps which have been taken at Dailuaine with regard to this kind of refuse, steep waters and so on?—Yes, sir, I have seen that.

26674. There they take the trouble of passing it after precipitation through a series of contacts bed?—Yes.

26675. And produce an excellent effluent?—I have no doubt.

26676. But do you think that is really necessary?—I am just afraid that in the course of time these beds may cause trouble. You will have putrefactive fermentation taking place.

26677. Is that likely to occur if they are properly managed?—Still, if there is percolation of this liquor into the soil it will almost certainly.

26678. These are contact beds?—Yes.

26679. They are cemented?—Oh, they are cemented; I did not know. Well, if these are properly managed they could give an excellent effluent.

26680. We have had evidence from Dr. Readman that he exposed fish (trout) for a week to a fluid which practically was the steep water and the wash water in the spent lees, after being simply passed through a sand and gravel filter, and of the e fish one died at the end of six days, but the other was perfectly well, and he deduces from that that this effluent was not noxious to fish. Does that commend itself to you; do you know of the experiment?—No, I do not know of the experiment.

26681. But it is what you would expect?—I would expect that. In the first place the difficulty is as regards time.

26682. This was rather a powerful experiment, was it not, making the fish live in the actual effluent itself?—Oh, yes, that was.

26683. But we may take it that it is your opinion, and you have had very great experience and made a great many examinations especially with fish life, within all these waste waters, that if they are uniformly carried into the stream as you suggest, they would have no bad influence on the fish of the river?—That has always been my opinion.

26684. Have you paid any attention to that fungus which appears from these refuses?—I have seen much of it and examined it.

26685. Do you know anything about its natural history; I suppose it comes from the seeds of the barley?—Yes, very much. The potale will produce it also.

26686. Potale will produce it also?—Yes.

26687. We have been told that the phosphates which are present in that are essential to the growth of the fungus; do you know any observations on that point?—Not particularly, but it is very well known that phosphates are essential to plant life of any kind.

26688. That is a general inference, is it not, that it is the phosphates; you do not know of any exact experiments?—The only thing I know is in regard to the growth of yeast, sometimes the phosphates are put in to encourage it.

26689. Each fungus has its own laws, has it not?—I have no doubt.

26690. You do not know of any experiments of this particular leptomyses?—No, sir, I do not.

26691. (*Sir William Ramsay.*) You speak of the torrefied product being made marketable and also of the possibi ity of its being burnt or overdone; what is its selling price?—Well, it has been fairly into the market now. According to the Highland and Agricultural Society's valuation it ought to bring five guineas per ton; they have been getting, I believe, as much as £5 10s. for it.

26692. Is there a prejudice amongst Scotch firms and several others against black manure?—Well, there may be; I am not certain that there is. At one time I believe firms had some objection to manure made from spent charcoal. I think they did not like the idea of its having been made from spent material, and that was black charcoal, but that is the only connection I can think of.

26693. Is it necessary to mix this black product with anything in the shape of super-phosphates?—No, sir, nothing at all. It has been used experimentally by some of the firms or agriculturalists who have got it, mixed with other things, but the producers of it never mix anything with it at all.

26694. Is it sticky or dry?—It is perfectly dry and powdery.

26695. Is that what we saw at Tamdhu, the brown charred powder?—A brown powder.

26696. Is it possible to collect the ammonia which is given off the final torrefaction, or whatever one may call it? Is there much escapes? Is it worth troubling about?—I understand that is under investigation just now. Attention was called to it recently. It is to the the interest of the distiller that he should allow as little ammonia to escape as possible. There will always be a little. If it could be collected suitably it certainly would go further to cover expense.

26697. It would not be very troublesome to collect it I think?—Perhaps not.

26698. You were telling Sir Michael about the condensed water from the multiple effect evaporators. It has been suggested to us that this condensed water will putrefy if kept; do you think that is the least likely?—I do not think that is the least likely. It cannot.

26998. There are traces in it of ammonia?—There are traces in it of ammonia and a little free acetic acid.

26700. (*Chairman.*) Any other organic acid; volatile organic acid?—I do not know of any there; there is acetic acid.

26701. (*Sir William Ramsay.*) It would be incredible that it should putrefy; a distillate of that kind—I cannot understand it; it has been at the boiling point, and there is practically no organic matter in it. I do not think that is at all possible.

26702. If there was any organic acid, there might be bacterial action?—The acetic acid will not putrefy or change in any way, and there is no organic matter. I have not a copy of my report with me, but I analysed that, and it is better than the burn water as regards solid matter.

26703. Another question which has been suggested to us is one upon which I should very much like your opinion, as to whether it would be a feasable way of disposing of pot ale itself to use it as a medium for the cultivation of yeast; to grow yeast upon it and make it serve as a sort of bed where yeast can be cultivated, to be sold or disposed of in any way that may appear desirable?—I have not heard of that at all.

26704. Do you think it is at all likely it should work? I should have said on first principles that it had already been fermented in the manufacture of the whiskey and given up all it could?—The yeast plant during alcohol fermentation performs a function. It converts saccharine substances, as you are aware, into alcoholic carbonic acid and it grows itself at the same time, and if it does not perform its life's work I do not see how it can grow.

26705. The only thing to be said in its favour is that the potale contains a considerable amount of phosphates and ammoniacal substances. Is it conceivable that the yeast might be induced to grow up upon these and multiply without necessarily causing fermentation in the ordinary way?—I cannot say as to that; I am not sufficiently acquainted with the life and functions of the yeast plant to know whether it would grow without performing these functions or not, simply because certain things were present while it was performing its functions.

26706. Of course these substances have been destroyed by the previous action of the yeast?—The great objection to a liquid such as potale is the nitrogenous bodies. If these could be got rid of by any process whatever, of course everything would be more or less innocuous

26707. There is another possibility which strikes me, and that is if the yeast requires sugar as a food, would it be possible to mix the potale with a certain amount of sugar and use it for the production of yeast; not for the production of alcohol, but for the production of yeast?—I have very little doubt the yeast would grow, but yeast is very largely a drug. It could be made in almost unlimited quantities if distillers wished to make it, and some of them make it and sell it in hundreds of tons. It may be easily made at a distillery, and any process for making more of it would be at a disadvantage.

26708. There has been no market for it?—There has been no market for all that can be made, so much so that only a few distillers make it.

26709. Have you any choice between the two processes of getting rid of the potale, the multiple effect followed by incineration, and the plan of passing the liquid pot ale up a trap into the flues from which hot gases are escaping, partly the waste heat from the stills and partly supplemented by coal?—Well, that depends upon the product. At Tamdhu they make a very marketable article, an article which is capable of being stored and used under all conditions. I have not seen any product corresponding to that from any other process.

26710. It is sticky stuff that comes out at the bottom?—It is sticky stuff and unprofitable as a market commodity, but if they can succeed in other places in making a marketable manure such as they have at Tamdhu, they will have the advantage of the waste heat from their stills, which Tamdhu has not at present.

26711. (*Chairman.*) There they lose all the water do they not?—Yes.

26712. And if it were a small stream that might be a serious difficulty, might it not, taking away the water from the stream and not returning any back to it?—I am afraid I misunderstood the question. I think I said at Tamhu the greater proportion of the water was returned

26713. I mean at Tamdhu?—I did not think of it in that light, but I see it would be a disadvantage.

26714. (*Sir William Ramsay.*) The product is in fact not marketable at present. There is this to be said against it; there must be a considerable expense at Tamdhu?—Oh yes, the price got for the manure barely covers the outlays, but it is hoped it will cover them a little more shortly.

26715. What is the plant they are putting up at Rothes?—It is the same.

26716. Only they are uniting several distilleries and working them altogether?—Yes, they are uniting four distilleries, and they are being connected to-day; one of them, Glan Grant, has been connected for a fortnight, and the other three are being connected to-day.

26717. Dr. Readman told us the manure is worth £3 a ton; there is an analysis which is given; I wonder whether you could tell us even very roughly what the value of such a manure would be; would it be possible to say so without a long calculation?—Well, first it would depend on the character of the manure whether it was marketable, even with these ingredients having nominal value in it. Very dry cinders work out at £5 17s. per ton.

26718. That is very considerable?—And the other about £2 10s. Oh, I observe that is medium dry paste, which is not marketable.

26719. Nor marketable, but the dry cinders would be of market value?—They would be marketable; if not for manure, at any rate for some purpose they would be marketable.

26720. Then another question I should like to ask; it has been suggested to us that this process might be applied for the treatment of pot ale:—first of all, evaporation by multiple effect to a syrup, then the addition of sulphuric acid to that, I presume oil of vitriol; then the addition of phosphate of lime very rich in carbonate, containing 60 or 70 per cent. of carbonate, a very poor phosphate; the result would be to form gypsum from the sulphuric acid, and the gypsum would take up the water, drying the whole material, and it is suggested that here would be produced an article containing sulphate of lime, a considerable amount of phosphate, the whole of the ammonia which was given off in the evaporation, and that it would be a valuable manure. Do you think that is a feasible process?—It would require calculating out, but it does not look well to begin with, making sulphate of lime from sulphuric acid. It is very expensive. Sulphate of lime is a drug in the market. Then it strikes me at first that the valuable ingredients would be so diluted that carried from a highland centre like that to centres where it could be largely employed would be costly, but I would not say positively without having an opportunity of working it out.

26721. I think the feature of the process was the idea of drying it by the formation of sulphate of lime?—Quite, but it seems to me that the proportion of water in sulphate of lime is so small that you would require to produce an enormous amount of sulphate of lime to combine with all the water present seeing there are only two molecules of water as hydrate in gypsum.

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26722. (*Chairman.*) We have had an analysis made of the distillate at Tamdhu. This was made on 25th April, 1904, and in 100,000 parts the oxygen absorbed in four hours was 4·70. There is the analysis (*exhibiting analysis to witness*); that is hardly distilled water, is it?—No, sir.

26723. You are producing a very large quantity of that?—Yes, almost equal to the amount of pot ale. I have analysed the spent lees for other substances than solid matter, and the spent wash the same, and I find that a good deal of the ethers and heavier alcoholics remained in the spent pot ale, and it strikes me this oxygen absorbed may correspond to these. I have analyses here of spent wash I have made for these components for another purpose.

26724. But that oxygen absorbed has a different significance there from what it has applied to an ordinary sewage effluent?—Yes, sir, I think these higher alcohols will be probably converted into higher acids there.

26725. At ordinary temperature within four hours?—Well, I should think so; not completely, perhaps, but whenever those higher alcohols are treated with permanganate of potash, that I observe is the process used, they are converted into corresponding alcohols.

26726. This means that besides acetic acid there is a number of alcohols?—Oh yes, sir, but they are not putrefactive.

26727. The amount of dissolved oxygen is also rather high you see?—(*Dr. McGowan.*) At the same time the volume that would go to the stream would be very small.

26728. (*Chairman.*) It is the whole of the pot ale at Tamdhu. (*The witness.*) Dissolved oxygen taken up?

26729. (*Dr. McGowan.*) At about 65° Fahrenheit, and I see that is given in three days; you may divide it by three for one day?—That is a feature I am not very familiar with, the absorption of oxygen.

26730. (*Chairman.*) Is it not possible that your condensed water is different from distilled water and requires some attention?—Yes, it may require some filtration; I do not think there is anything putrefactive in it.

26731. It will take up oxygen in a stream?—Yes, I think it would.

26732. (*Colonel Harding.*) To an appreciable extent?—Yes, probably, with time.

26733. (*Chairman.*) 4·7 in four hours in 100,000 gallons.

Mr. John H. Fullarton, M.A., D.Sc., called in; and Examined.

Mr. John H. Fullarton, M.A., D.Sc.

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26734. (*Chairman.*) Mr. Fullarton, you were formerly scientific adviser to the Fishery Board for Scotland?—I was, sir.

26735. And you have given considerable attention to the pollution of streams, especially by whiskey distilleries?—Yes, I have.

26736. And you have given evidence on this subject in courts of law?—I have given evidence.

26737. The refuse from whiskey distilleries are of two great classes; there is first pot ale, and then there is the steep water, wash water, and spent lees?—Yes.

26738. Let us take the pot ale first. Various methods have been devised for the disposal of that; first to treat it by land, it being put on land?—Yes.

26739. I suppose where there is an adequate quantity of suitable land in the neighbourhood of the still, and the pot ale is applied with judgment, a very large quantity may be disposed of in that way?—Yes, that is so, and to the improvement of the grass crops.

26740. Being what is often called a strong manure it requires careful application?—It does.

26741. But with that care it may be largely used?—It may be.

26742. I suppose if in the neighbourhood of each distillery there was an adequate quantity of suitable land, that would be the best way of disposing of it?—Oh yes, that would be the cheapest way.

26743. Then there is the method by evaporation, followed by what we may speak of as torrefaction, and there is another method which is simply torrefaction, the pot ale is poured into a large tower and subjected at once to heat without previous evaporation. You have paid considerable attention to that process?—Yes, I have.

26744. You can speak favourably of it?—Yes, I have erected a plant.

26745. In the first process where there is the evaporation and then the torrefaction of course the water of the evaporation is returned back so that there is no loss of water?—I presume so.

26746. But in the second process, which is torrefaction alone, the whole of the water is discharged into the atmosphere as vapour?—Yes, it is all discharged as gases—the whole of the pot-ale barring the sediment.

26747. If that still is in the habit of drawing its water from a relatively small stream and does not return to that stream any of the water it takes from it, that may become a serious objection in this simple torrefaction process?—I do not know any stream where it becomes much of an objection because the supply of water is so adequate; it is more than adequate.

26748. Can you make any statement about the nature of the water after condensation which comes from the evaporation?—Well, I will tell you what I have done. I have taken the waste heat of the flues and utilised it by means of a suitable heater to heat the pot ale, and I have divided the liquid mechanically after it has been what I might call superheated and discharged it into the hottest part of the stalk several feet above the entrance of the flue. The result is well seen, for example, when you put on a new fire. Formerly black smoke was given off from the stack, but the smoke no longer is black, it becomes blue, and when the fires get red all you see is steam issuing from the top of the stalk. I have never attempted to capture the gases given out of the stalk.

26749. When you have the evaporation which is taking place before the torrefaction begins, the water of that evaporation, the condensed water of that evaporation comes back?—Of course I have not specially examined that, though I have seen it at work.

26750. Can you speak of the vapours which are sent off by this process of torrefaction as being at all noxious?—No, I do not think they are.

26751. They can be smelt, can they not, in the neighbourhood; have there not been complaints of the odours?—I did hear a complaint once upon a time at the very beginning, but they raised so many bogies about what was likely to happen that I paid no heed. In the first place we were to pull down the stalk by discharging the heated liquid into it. I do not pay much attention to that. I never was able to smell anything.

26752. If that were, it would be an imperfection in the process; the combustion would not be adequately complete?—I think the combustion is so perfect that you really cannot smell anything. At least that is what I find.

26753. Now can you make any statement as to the cost of this process? In some cases, is it not so, the heat of the stills can be utilised?—Yes.

26754. And in some cases it cannot, and the whole of the process has to be carried on by independent combustion of coal?—I have not seen it, except in one instance. I have seen it at work at one distillery, but generally speaking the method that they adopted on Speyside, which I know pretty well, is an uneconomical method. Working by the pot still is an uneconomical method. When I saw this method at work I at once concluded that there was a great deal of waste heat here. Is it or is it not possible to tap that waste heat without any additional cost for fuel? And after making experiments I first ascertained the quantity of coals—had them measured—which went into the furnace of the copper and stills; I had two small stills to deal with and the still wash and also the coal to the boiler. Well, I could tell exactly from the Excise returns the quantity of work to be done in the stills and in

the copper, but it was not so easy to ascertain the quantity of work to be done by the power boiler. I made up my mind there was a great loss of heat. I could not quite condescend on the exact figure, but the coal bill was something like forty-two tons per week, and I concluded there was a loss of heating power. I forget whether I took eight or nine pounds of water evaporated per lb. of coal, but I concluded there was a loss of heating power to the extent of about seventeen tons.

26755. Out of forty ?—It was seventeen or thirteen, I could not be exactly sure at this moment. I have not been home for a little time to get my papers. All that heat cannot be lost by radiation ; it must be lost in some other way, and when you see red hot flame belching forth at the top of a sixty foot stack, you can only come to the one conclusion. Therefore I asked myself what is the easiest method to get hold of this waste heat and make it do further work ? At this stage I associated with myself a mechanical engineer—I am not an engineer—and we have devised a coil for placing in the flues. Through this coil was passed ale from the burnt ale tank, which was received in the burnt ale tank at something like 175° Fahrenheit, but which lost heat so that it was only about 130° Fahrenheit when it came to our coil. Then we had the coil made of solid drawn copper, so that it would stand a very high pressure, with the object of course of getting the material superheated. We then took and divided it mechanically and discharged it into the stalk, and the results after some weeks' working came out exactly as I anticipated ; we were able to do what I had promised we could do, and we destroyed for I forget how many weeks 100 tons of ale per week. Sometimes I admit we were behind in the destruction of the ale produce ; sometimes we were ahead. I remember within ten days we had actually to let cold water into the ale tank to keep our pipes filled. We had to have the liquid continually circulating through the heater.

26756. Where was this ?—This was at Ben Rinnes distillery.

26757. Is it still carried on there ?—It is still carried on. It was carried on under skilled management for some weeks. I was peculiarly situated. I was retained by the Duke of Richmond and other riparian proprietors against the distillers. I went up there ; I was interested in the question ; and I had made some experiments with a view to the recovery of the material, and the distillers there made a proposition to me, whether I could help them or not. I said I believed I could, and I got the consent of the proprietor's agent. I got the contract signed on 23rd December. Our proof came on early in February, I had to have everything erected in a few weeks' time ; everything was erected and it was reported on by the agent of the proprietors—the superintendent of fisheries—for the proprietors. On 17th January we had done exactly what we had promised. Since then the apparatus has been in unskilled hands, but I consulted recently the superintendent of fisheries, the representative of the proprietors, and he admits that in good weather we destroy three quarters of the ale produced, and that, mark you, without 1 lb. of additional coal consumed.

26758. The waste heat is adequate to destroy at least ? —In this instance at least, I cannot speak for others ; of course I have not gone into their figures.

26759. And what is the product there of the destruction ?—It goes into the atmosphere. We drove a small door into the bottom of the stalk, and we have now about on an average a barrowful, well, not 1 cwt., of practically carbon at the foot of the stalk in the week ; that is all the material unconsumed.

26760. And the water of the potale goes into the atmosphere ?—The water of the potale goes into the atmosphere ; you see the steam issuing from the top of the stalk and I have no doubt there are other gases along with the steam.

26761. I suppose the loss of water is a matter of no consideration at all, because there is abundant water everywhere ?—Oh, it is neither here nor there.

26762. Have you any experience of other treatments ?— Yes.

26763. For instance, by filtration or by bacterial beds ? —I have seen both beds at work and examined the products ; not I mean to say chemically, but I examined the bacterial effluent by putting my hands in it and smelling them afterwards. I have seen the filter beds also at work.

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26764. Simple filter beds ?—Simple filter beds.

26765. Those are ineffective ?—Quite ineffective.

26766. Are you acquainted with the plans adopted at Mortlach ?—Yes, I am ; I saw those beds after they were put down ; I am not sure whether it was under Mr. Thuddicomb's management, but I saw those beds in April.

26767. Have you seen them recently ?—No, I have not seen them recently, but of course my objection to them is a biological objection that here you have got a very acid product, and it is continuously producing acid, at least for a considerable time, and as far as I know anything of bacteria, they do not want an acid medium if they are to live and thrive well.

26768. As at present worked the pot ale is neutralised by lime and precipitated before it is thrown on to a number of contact beds, seven, I think, in number in succession, and the effluent from the last seven contact beds is thrown on to what is called a percolating filter, a final percolating filter, and by that means they assert that they got an effluent which at all events is a very fair effluent, and coming very nearly within so satisfactory a standard as that of the Mersey and Irwell Rivers Board ?—Yes, well I cannot say. I have had such statements made to me several times. While I was there I said, let us see your analyses and then we can deal with it.

26769. The analyses ; the absorbed oxygen, for instance ? —Well, of course I am not a chemist.

26770. Is very nearly if not quite within the Mersey and Irwell standard, showing that at all events if not perfect, it is a process which cannot be ignored ?—If it is a partial purification process, there can be no doubt about that.

26771. Then with regard to the other, the steep waters and the washings and the spent lees, we have been told that those, if they were discharged uniformly into a stream of adequate volume, might be so discharged without creating any harm at all. Is that also your opinion ?— Well, I would hardly say that. I do not think it is a good thing to discharge them uniformly. It would be much better to discharge them with a splendid spate in the rivers, if that could be obtained.

26772. (*Col. Harding.*) Store them until such time as there is a spate ?—That would even be better, I think, than discharging them uniformly, no matter what the rainfall or the flow of the burn may be ; so far as fish is concerned, I know that is what I should desire.

26773. (*Chairman.*) Are these waste materials injurious to fish ?—Oh, yes. I think the most injurious of all is the barley steep water. I made experiments on fish eggs.

26774. Can you make a statement of those experiments ?—Well, it is so long ago that I have not the details of them, but I can state them, roughly speaking.

26775. We have been told of an experiment by Dr. Readman in which he exposed a couple of trout to the effluent itself ; that is to say to the steep water, the wash water, and the spent lees, joined together, simply passed through a sand and gravel filter, a continuous sand and gravel filter. That effluent was carried into a tank and two trout were placed in the tank and left there for a week. One died on the sixth day, and the other was in perfect health on the seventh day in the actual effluent itself. Does that correspond with your own experience ?—Not quite ; I made certain experiments with the view of giving evidence in the Macallan case.

26776. May I ask this question first of all : is there anything in these effluents which is actually noxious to the fish themselves, or do they become noxious to the fish because they give rise to the formation of fungus ?— Well, they become noxious to the fish in the first place from the want of oxygen in them.

26777. But then if you are discharging these in adequate quantity into the stream, would they so reduce the oxygen of the stream as to any have effect upon the fish life ?—Not in a large body of water. But with reference to the fungus, what happens is that when the fungus becomes loose it gets entrapped in the gills. I experimented with gold fish and found this—that the gills got blocked up and a process of inflammation was set up

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and the fish died. But with reference to the effluents themselves. I have experimented with all of them and I cannot say with what result at this moment, but I remember that the barley steep water was the most poisonous of the lot.

26778. But to what extent was it poisonous?—If you put in, for example, a parr, which is the young of the salmon or salmon kind, within a very few seconds it was dead.

26779. That is to say into the untreated waters?—Into the untreated waters and the barley steep.

26780. As it is coming from the barley?—Coming from the barley, that is so.

26781. (*Sir William Ramsay.*) Is it due to the want of oxygen in the barley steep water?—I do not think so, because for example the old fish does not die anything like so quickly in the effluent without oxygen. I do not think that the want of oxygen would kill it so quickly; I do not know whether it was even in consequence that it was killed; it was more like an active poison; what the poison is I do not know.

26782. (*Chairman.*) Would that poison survive after the effluent had been treated in various ways, do you think?—I think it would be quite possible to destroy the poison somehow or other.

26783. You cannot give us any very exact statement about that save that you remember?—About the barley steep?

26784. For instance, you did not oxygenate the steep water and then see?—Oh, no; of course, there were various other experiments, but that was with the two fluids, to ascertain which had the most deleterious influence.

26785. This striking experiment of Dr. Readman, these trout living apparently for a whole week, in the undiluted effluent?—In the one effluent or the mixture?

26786. The mixture?—Yes.

26787. The volume of water in the steep water is greater than any other than the wash water and certainly than the spent lees; in the spent lees it is very small?—In the spent lees it is very small. I do not know what factor you allow, but it is something like 12½ to 15 gallons ale per bushel malted.

26788. I was asking what was the relative proportion of the washings to the steep water?—Well, I am afraid that you cannot strike any figure for barley steep water.

26789. Here it is, 12,000 gallons of barley steep to 6,000; it is about twice the volume, and the steepwater is about twice that of the washings?—Well, it is sometimes nearer twenty times, because in steeping barley they sometimes retain the water; in other cases they simply allow the water to run right through.

26790. (*Sir William Ramsay.*) Then, of course, you get a larger volume?—It quite depends on the method of steeping.

26791. In Dr. Readman's experiment it is only fair to say it was run through?—Well, you never can tell in that case the exact amount. I have seen a very very strong stream going through, and I have seen it without any stream.

26792. (*Chairman.*) Is this fungus a single fungus or more than one species?—The one I saw was Leptomitus, or Apodea lactea, the same species, with a different generic name. It is one of those white fungi.

26793. It is one fungus?—It is one fungus; that is the only fungus I examined; that is the chief one.

26794. (*Sir William Ramsay.*) Is it the only one found?—No, I think there is another one—Leptothrix.

26795. (*Chairman.*) That is the important one; the other is in smaller quantity, under ordinary circumstances?—Yes.

26796. I suppose the spores are in the barley?—That is assumed so.

26797. Do you know anything about what are the conditions which determine its growth?—Well, not except the ordinary conditions of moisture, certain temperature, light, and what not.

26798. It has been stated to us on one occasion that the presence of phosphate is necessary for its existence. Do you know of any accurate observation as to that?—I know none whatever. I only examined it from the standpoint of fish; not chemically at all. We use chemistry as a handmaid.

26799. Then briefly, these various refuse of which we are speaking, the steep water and the wash water and the spent lees, which are very small, might be discharged into the stream without any injury to the fish provided that there is a due proportion observed between the quantity discharged at any moment and the quantity of water into which it is discharged?—Yes, quite so; it will not be very deleterious if you have an enormous volume of water.

26800. (*Sir William Ramsay.*) Have you fished in the Spey?—Yes, I have.

26801. Do you notice that there is any difference between what it is now and what it used to be?—I have not fished in it to that extent. I know the allegation on one side and the other, but one does not always accept what one side or the other says.

26802. How is one to know what is the truth of it? Is there much of this fungus growing?—When I examined it in 1898, and one or two years after, we had certain places immediately below small pools, at Ringoom and Bogandine receiving effluents from the distillery, and a fairish quantity remained there. It can be kept quite clean when the distilleries shut down, but I have seen the Fiddich for over a mile clothed from bank to bank with fungus.

26803. What is the Fiddich?—It is a little stream that goes into the Spey at Craigellachie, and there are about seven or eight distilleries on it. I have seen it clothed for months from bank to bank with fungus.

26804. (*Colonel Harding.*) When was that?—1899 and 1900.

26805. (*Sir William Ramsay.*) Has there been any improvement in the Fiddich since?—I have not seen the Fiddich for some years. I have no doubt there is an improvement, but I cannot say.

26806. In your experiments on the destruction of fish by the fungus, did you expose them to the fungus, or were they put into the river, or how?—I put the fungus in Loch Katrine water in a laboratory in Glasgow along with goldfish.

26807. (*Chairman.*) In regard to these experiments with fish, you have your notes at home?—Yes.

26808. Can you get them?—If I can get my precognition as given to the agents in the case I could give you all the information; I do not know whether I have the notes handy or not.

26809. When you correct your evidence, perhaps you will put in as an appendix some exact statement?—If I can get the proof from the pursuers' agents.

26810. It will be an advantage to us to have your exact experience?—Yes.

26811. (*Sir William Ramsay.*) Do fish spawn in the Fiddich, for example?—Yes.

26812. Does the presence of this fungus destroy their eggs, or does it destroy the young fish?—The only destruction I could find was of the fish themselves. It gets into their gills and round their gills.

26813. It is mechanical?—It has a mechanical effect.

26814. I remember we were told the fish do not come up to spawn as usual for several reasons. First, they know it is a dangerous place and avoid it; and secondly, they feed at the mouth of the Spey, and they get out of the habit of coming up to spawn. But it has been said that they do not come up to spawn in the way that they used to?—Well, I do not know. You will get very good statistics in Macgregor's reports to the Fishery Board, part 2. He counts what he calls spawning beds in each tributary of the Spey as seen by his watchers, and I think they will give you a very good index whether there are fewer beds or not in the Fiddich than usual.

26815. But you do not happen to know?—I do not happen to know. I know the allegation about the fishing and netting and that sort of thing. The Duke of Richmond has taken off several miles of nets about Orton, and that ought to improve matters.

26816. Does the scum on the river do any harm?—Yes, it is quite possible. There is a pool, which is below

Macallan Distillery, at the tunnel, which is between Craigellachie and Aberlour, and while the ale was being discharged into the river there was always a great quantity, perhaps six inches thick of frothy scum, which is very much like what you see on the coast when a heavy sea has been beating on the shore, where there is plenty of seaweed. I presume it is due to the albumen.

26817. But does it do any special harm?—Oh, you cannot fish the place.

26818. While the scum is there it is not perpetually there; only when they turn out pot ale or one of the products?—It was there continually in 1898 when I examined before the distillers did anything towards dealing with the effluents.

26819. You are sure it is connected with the distilleries?—I never saw any fallacy in the argument which led one to that conclusion. You only get it where you get albumen or some such material coming in and you only get it below those discharges; it is lost, quite lost, after you get down stream.

26820. (*Chairman.*) Mr. Macgregor's report are reports to the Fishery Board?—They are reports to the Fishery Board.

26821. Ordered by the Fishery Board; he is their inspector, I suppose?—No, he is not; he is the inspector of the Spey District Fishery Board and the Salmon Inspector asks for reports and he only gets them by favour. He year by year reports on the condition of the fishing of the Spey.

26822. Who are the Spey Fishery Board?—The proprietors of salmon fishing on the Spey, with the Duke of Richmond as Chairman as the largest proprietor.

26823. They alone form the board?—Yes, they form alone the board.

26824. There is no other representative on it only the riparian owners?—Only the riparian owners.

26825. (*Sir William Ramsay.*) To come back to your process, how did you manage to get this potale into the chimney. Was it dammed up?—The pot ale ran from the large still to the ale tank, where they had a Worthington pump, and we filtered it. Of course, we could only in such a short time make use of the plant which they had; theirs was a very old ale tank; after being in the tank we got most of the material in suspension out and it was driven then by force through those coils, about eighty to 100 feet long of copper,—solid drawn copper coil—two and a-half inches I think it was in diameter; I cannot say at this moment; it was continuously forced through; it came out from this and went into a smaller pipe, a three-quarter inch pipe, I think; then it was discharged into the chimney after going through a rotary motion at the nozzle.

26826. Discharged at a higher point in the chimney? About six feet, if I remember rightly, above the top of the flue and it was discharged, in the form of fine rain, like Scotch mist.

26827. Yes, quite, these coils were heated by the waste heat of the flue?—The waste heat, yes.

26828. Were there any obstructions in the coils; did they admit of blocking?—No, there were coils in there before we went; they were very amateurish indeed; they had twenty-four openings to the air, I think; I forget how many; twenty-four openings discharging the steam with the result that the coils became coated inside in a very few days and then they were burned. We tried to prevent that by keeping the liquid in motion, to prevent it becoming gaseous, until it got into the hot part of the stack. It must be maintained as a liquid under great pressure or great heat, and then of course once it gets exit at the point of the stalk it at once becomes gaseous.

26829. Was there anything to show that the chimney became coated over with deposit?—Yes, the chimney did become coated over with a deposit slowly as it impinged on the inner wall as it went up; if I remember rightly the particular size of nozzle we had could discharge it at about sixty pounds pressure, fifteen feet in a vertical direction. It impinged on the sides, and there was a tarry-like material on the sides very soon; when the chimney was sufficiently hot and sufficiently dry this took fire.

26830. That is how they got rid of it; the mineral matter must have fallen to the bottom; I suppose it would be very small?—A very small quantity.

26831. There is a phrase which caught my eye which I think we might ask about: the difficulty of combatting trickery of distillery servants at Speyside?—I have been acting on both sides, and I am very sorry to say trickery is not confined to one distillery. They put in private pipes and humbug the watchers till they are caught.

26832. Is it not possible for the owners of distilleries, who we presume are perfectly honest, to guard against that?—If they dug up every pipe; but it is impossible unless they take up every pipe to see the connections just as the excise officers see them.

APPENDIX TO MR. FULLARTON'S EVIDENCE.

EXPERIMENTS TO DETERMINE THE EFFECTS OF DISTILLERY EFFLUENTS, VILLAGE SEWAGE AND VARIOUS WATERS FROM STREAMS ON FISH LIFE.

1. *Effluents filtered through gravel and sand for about 50 feet verticcally and 50 yards horizontally. The Effluents comprised Barley Steep Water, Burnt Ale, Spent Lees, Washings of Vats produced at a Distillery along with ordinary rain water.*

Date.	Fish.	Result.
1898, December 13	Minnow	Died in 8 minutes.
„ „ 15	Parr	„ „ 5 „
„ „ 15	River Trout	„ „ 7 „
„ „ 22	Salmon Eggs	„ „ less than 2½ hours.
„ „ 24	Salmon Alevin	Heart's action slowed in 7 minutes and ceased in 40 minutes.
„ „ 25	„ „	Heart's action slowed in 7 minutes and ceased in 23 minutes.
„ „ 25	Spey Trout	Lay on side in 3 minutes; all movement ceased in 25 minutes.
„ „ 25	Salmon Alevin	Heart's action slowed in 6 minutes and ceased in 33 minutes.
„ „ 25	Spey Trout	Dead in 3 hours.
„ „ 27	Clean Male Salmon, weighing 6½ lbs.	Lay on side in 4 minutes; all movement ceased in 28 minutes.
„ „ 27	Clean Female Salmon, weighing 6½ lbs.	Lay on side in 3½ minutes; all movement ceased in 22 minutes.
„ „ 28	Male Salmon direct from Sea, weighing 6 lbs.	Lay on side in 2 minutes; all movement ceased in 9 minutes.
„ „ 28	Male Kelt Salmon, weighing 15 lbs.	Lay on side in 3 minutes; all movement ceased in 12 minutes.
1899, January 12	Salmon Parr	On side in 2¾ minutes; died in 13½ minutes.

2. *Similar Effluents treated with Milk of Lime and filtered.*

1891, December 28	Salmon Alevin	Dead in 4 hours.

3. *Liquid By-products from Distillery.*

(1) *Burnt Ale.*

Date.	Fish.	Result.
1898, December 22	Salmon Eggs	Died in less than an hour, as determined by opalescence. Embryo inside egg dead sooner.
„ „ 23	Ditto	Ditto.
„ „ 25	Salmon Aleoin	Died in 10 minutes.
1899, January 10	Salmon Parr	Turned on its side in 3½ minutes. All movements ceased in 26 minutes.
„ „ 13	Ditto (Ale stood in vessel in air for 3 days.)	Turned on its side in 24 minutes. All movements ceased in 43 minutes.

(2) *Spent Lees.*

1898, December 22	Salmon Eggs	Died in less than 1 hour.
„ „ 23	Ditto	Ditto.
„ „ 25	Salmon Aleoin	Died in 18 minutes.
1898, January 10	Salmon Parr	Exhibited nervous twitchings of head at once, then turned on its side in 5 minutes, and all movements ceased in 42 minutes.
„ „ 13	Ditto (Lees stood in vessel in air for 3 days.)	Turned on its side in 2½ minutes. Movements entirely ceased in 2 hours.

(3) *Mixture of Burnt Ale and Spent Lees.*

1998, December 28	Spey Trout	First placed in village of Aberlour sewage for 6 hours, where it was quite lively and apparently healthy, then in above mixture, when it died in 13 minutes.

(4) *Barley Steep Water.*

1899, January 10	Salmon Parr	Turned on side in 1½ minutes. All movements ceased in 13 minutes.
„ „ 13	Ditto (Stood for 3 days in open vessel in air.)	Turned on side in ½ minute. All movements ceased in less than 1 minute.

(5) *Washings of Vats.*

1899, January 11	Salmon Parr	Died in 17 hours.
„ „ 12	Ditto (First washings only.)	Lay on side in 1 hour. All movements ceased in 1¼ hours.

4. *Sewage, Domestic, from Village of Aberlour.*

1898, December 22	Salmon Eggs	Began to be hatched on 23rd. All hatched by 27th, and Alovins continued healthy.
„ „ 28	Spey Trout	Healthy till taken from liquid in 6 hours, when placed in mixture of burnt ale and spent lees, where it died in 13 minutes.
1899, January 10	Salmon Parr	Healthy at end of experiment, viz., 3 days afterwards.

5. *Water of Tail Race (said to contain no Distillery By-products, except very Dilute Barley Steep Water).*

1898, December 22	Salmon Eggs	Died in less than 4 hours.
„ „ 23	Ditto	Ditto.
1899, January 8	Salmon Parr (To water was added small quantity of Fungus. Apodea lacteas.)	Turned on side in 2 hours 55 minutes, and in 20 minutes thereafter all movements ceased.

6. *Water from Stream above Point of Discharge of Distillery Effluents into it.* (*No Fungus in Water.*)

1899, January 8	Salmon Parr	Fish perfectly at ease, with gill-covers and fins moving in normal rhythm. Remained there for 26 hours, when experiment ceased.

7. *Water from same Stream 60 yards below Entrance of Distillery Effluents into it, but without other additional Effluents entering it.* (*Fungus present in Water.*)

1899, January 8	Salmon Parr	Turned on its side in 19 hours; died in 22 hours.
„ 9	Salmon Parr (After water had remained 20 hours in vessel open to air.)	Sick in 2½ hours; died in 6½ hours.

8. *Spey Water, 10 yards below Entrance of Stream, Carrying Distillery Effluents, with a small quantity of Fungus coating a Stone placed in it.*

1899, January 12	Salmon Parr	Died in 6 hours. Fungus was entrapped in the gills.
	River Trout (Water from same place, but without Fungus.)	Living 24 hours afterwards.

EIGHTY-FIFTH DAY.

Thursday, 8th February, 1906.

PRESENT.

The Right Hon. The Earl of Iddesleigh (*Chairman*), presiding.

Sir Michael Foster, K.C.B., F.R.S.
Major-General Constantine Phipps Carey, C.B., R.E.
Colonel T. W. Harding, J.P., D.L.
Sir William Ramsay, K.C.B., F.R.S.
Mr. W. H. Power, C.B., F.R.S.

Mr. F. J. Willis (*Secretary*).

ALSO PRESENT.

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.

Mr. James Hendrick, B.Sc., F.I.C., called in; and Examined.

26833. (*Sir Michael Foster.*) Mr. Hendrick, you are a Bachelor of Science, University of London; a Member of the Council of the Institute of Chemistry; the Lecturer in Agricultural Chemistry, University of Aberdeen; the Chemist to the Highland and Agricultural Society of Scotland; and the Public Analyst for the Counties of Aberdeen, Banff, and Nairn?—Yes.

26834. For several years you have paid very close attention to the distilling industry and its products?—That is so.

26835. You have been kind enough to put in a memorandum. Would you be willing that that should be printed?—That statement is a mere sketch and I hope to supplement it considerably now.

26836. Perhaps it is rather too imperfect to put in as it is now, you think?—Yes; but I have prepared a considerable number of tables which give analyses of effluents and bye-products, and I shall be glad to put these in.

26837. The elements which may cause pollution are, first, burnt ale or pot ale; then spent lees; then steep water; and, finally, wash-up water?—Together with general sewage.

26838. I believe you can put in analyses of these various effluents?—Yes. I have prepared tables of analysis of all these effluents.

26839. I think the Commission would desire that you should put them in as evidence?—I shall be pleased to do so. (Appendix I.)

26840. The first, and perhaps the most important, in one sense, of these pollutions is the burnt ale?—Yes; it is more important than any of the others, both in its polluting power, and in its value as a substance from which by-products may be recovered.

26841. You have paid considerable attention to the composition of burnt ale, have you not?—Yes, I have made some investigations into the composition of burnt ale.

26842. It contains a very large quantity of nitrogenous matter, and also of non-nitrogenous matter, does it not?—That is so. It is a very concentrated effluent to be allowed to escape into rivers. The late Sir Edward Frankland pointed out as far back as 1868 in a report to the then Royal Commission on the Pollution of Rivers, that it contains about thirty times as large a proportion of polluting material in solution and suspension as ordinary sewage. I should be inclined to say from my analyses that it is from thirty to fifty times as great in polluting power as average town sewage. (*See* Appendix I. Tables I and II.)

26843. Have you made any study as to what the various nitrogenous matters are?—I have, to some extent, and I have a statement here of the nitrogenous matters in two samples of burnt ale of which I made a more detailed study. I must say that I failed to identify a very large portion of the nitrogenous matters by any of the ordinary means of separation. (*See* Appendix I., Table VIII.)

26844. I take it that it is a very complex substance?—It is a very complex substance indeed, containing nitrogenous matter in all stages from proteids down to ammonium compounds.

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26845. Would you briefly state a few of the more important nitrogenous substances that you could recognise as constituents of this burnt ale?—I will take a particular sample of burnt ale concentrated to syrup which had almost 2 per cent. of nitrogen.

26846. It had been artifically concentrated?—Yes, it had been artifically concentrated after being filtered. Proteids, which were salted out by zinc sulphate, represented 0·65 per cent. of nitrogen of the total 1·99 per cent.

26847. They would be what kind of proteids?—They seemed to be very complicated; and I did not attempt to identify individual proteids. Some experiments which I made in their precipitation by various re-agents appeared to indicate that they formed a complicated mixture. (Appendix I.) Similarly, peptones, precipitated by phospho-tungstic acid from the solution from which the proteids had already been removed 0·19 per cent. of nitrogen; then amido compounds 0·14 per cent., and ammonium compounds 0·15 per cent. But that still left in undetermined compounds, by difference, 0·86 per cent. I may say in this particular solution I used a number of different methods of precipitation, both for proteids and for determining peptones and other classes of nitrogenous substances, and found that every agent I used produced a different result. If I precipitated first with phospho-tungstic acid and afterwards with tannic acid I would get one set of results, while if I used the same reagents proceeding in the opposite direction different results were obtained. I arrived at the conclusion that we had a very complicated mixture of proteids and of their decomposition products in all stages of disintegration (Appendix I.)

26848. From what we may call the natural proteid right down to very simple ammonium compounds?—Down to very simple ammonium compounds. One could hardly draw a line anywhere and say there was so much of one and so much of another compound present, because we were dealing with compounds undergoing disintegration and representing all degrees of molecular complexity.

26849. And carbohydrates are in considerable quantity?—Yes, there are carbohydrates in considerable quantity, apparently chiefly as dextrin.

26850. Chiefly dextrin?—Chiefly dextrin. I conclude that from the fact that after the removal of the proteids, alcohol gives with burnt ale a gummy precipitate, which dissolves readily in water and is strongly dextro-rotary. On hydrolysis with mineral acids the dextro-rotation diminishes, and the copper reducing power increases.

26851. Is there a great variety of dextrins?—I take it there is a great variety of dextrins. There is no starch, and the sugar is practically a very small quantity.

26852. A small quantity of sugar?—A small quantity of sugar.

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26853. What kinds of sugar?—I did not identify them. But I made some determinations of the cupric-reducing power of samples of burnt ale from which proteids had been removed, and came to the conclusion that a small quantity of a reducing sugar was present. I also estimated that the total carbohydrates in solution were about ½ per cent. of the burnt ale.

26854. You speak of the pot-ale as decomposing very slowly. Of course the pot-ale that comes from the pot or still contains no living organisms whatever?—No; it is free from organisms.

26855. But you say that even when it is exposed to the action of decomposing organisms it resists decomposition largely?—Yes. Comparatively speaking, it decomposes slowly. I came to that conclusion taking samples and putting them into vessels which had already contained decomposed samples and which were contaminated with the organisms which cause decomposition. In the experiments in question I was imitating on a small scale the septic tank, and I found that as compared with ordinary sewage the decomposition of burnt ale was comparatively slow. But that, I take it, might be anticipated from the much greater concentration and from the chemical composition of burnt ale.

26856. You have not made any observations with a very diluted pot-ale?—No. The burnt ale with which I worked was only diluted with proportional quantities of lees, steep water, etc., to represent the total effluents of a distillery.

26857. The probability is that if it were diluted it would rapidly fall a prey to the decomposing organisms?—I have no doubt it would. But there would be more difficulty than in the case of urine, which I was taking as a standard substance which forms a large portion of the polluting matter of ordinary sewage. Urine will undergo change to ammonium compounds without any necessary supply of oxygen, whereas in pot-ale there is very little nitrogenous matter which would not require oxidation to break up the molecule and produce simple compounds like ammonium compounds.

26858. What makes you think so, not having accurate knowledge of what its constituents are?—I conclude, from what I did, that the nitrogenous constituents are of a much more complicated nature than urea, and so far as we know, compounds like proteids and the more complicated products of their breakdown require some oxidation or else complicated anaerobic changes, producing a variety of products, before they yield simple inorganic compounds.

26859. The decomposition which you might expect would not be so simple as that of urea?—A very large part of the nitrogenous matter of ordinary sewage is derived from urea.

26860. But from its very varied constitution this pot-ale would seem to present a very suitable pabulum or medium?—I did not mean to convey at all that it is not a suitable medium for the growth of organisms, and if I have done so I wish to correct such a false impression at once. If you introduce organisms into it it decays rapidly. What I had in my mind was a comparison with sewage, and especially with the urine of sewage, where the change to ammonium compounds takes place so very easily.

26861. So that supposing there were organisms present in the place to which this pot-ale was discharged, especially if the pot-ale is very largely diluted, you would expect a very considerable quantity of decomposition?—Exactly; complete decomposition, if the conditions are favourable.

26862. And therefore no nuisance?—And no nuisance. I hope to deal with that further on.

26863. Then the steep water. That varies in quantity, does it not, according to the method adopted in steeping?—Yes, according to the method adopted in steeping. When I first came into contact with this question, all, or nearly all, the distilleries steeped by using two steeps or three steeps The first steep water was always much the dirtiest and the most liable to decomposition; the second was less so, and the third was almost clear water. But now some distilleries, at any rate, use continuous washing with water. There is a great quantity of water used, but the water itself is less polluted.

26864. That is per unit of water?—Per unit of water Some of the samples that I have analysed of the continuously running water show hardly any difference from ordinary running water, except that at the very start of the steeping there is a little pollution.

26865. But if the whole of that steep water is collected, the whole mass represents very considerable pollution?—Yes. The first steep water may represent a very considerable amount of pollution, especially in the case of foreign barley. In one analysis which I have here the total solids from American barley were 0·493 grms. per 100 c.c. From another, also foreign barley, they were only 0·066, and from another, a home barley, they were 0·0092. Those figures show a very great variation in the amount of solid matter which may be present in the steep waters from different barleys. (*See* Appendix I., Table V.)

26866. Will you put in those analyses?—Yes.

26867. Then steep water, in contradistinction to pot-ale, does contain a very large number of organisms?—Yes, a very large number. It contains a very large number of fungoid organisms, derived from the barley, I presume. One generally finds that it undergoes decay rapidly, and the more polluted samples which very soon decay are filled with fungoid growths.

26868. Is it probable that the spores of the fungus—the *Leptomitus*—comes very largely from this steep water, do you think?—I am not able to say.

26869. Have you studied that fungus at all?—I have merely recognised it nearly everywhere where there was distillery pollution, but I have not studied its life-history.

26870. You have not formed any opinion as to whether the spores are very widespread?—No; except that I have found it everywhere where there is distillery pollution.

26871. But where there is distillery pollution there is probably steep water being discharged?—That is so.

26872. It is at least possible that that steep water contains a large quantity of the spores of the fungus?—Yes.

26873. Which, meeting with a proper element, more especially the polluted pot-ale, thrive to a very large extent?—That is so. I examined one particular sample of steep water after allowing it to settle in order to find out whether there was *Leptomitus* present, and I did not find it. I found a variety of other organisms, but nothing which I could recognise as *Leptomitus*. I may not have been giving it the proper conditions for growth—very probably not.

26874. Then as to the methods of disposal of these various effluents. They have been and still are—at any rate, pot-ale is to a certain extent—used as a food for cattle?—That is so. It is still used just round distilleries as a food for cattle. But the difficulty arises when the distilleries become large or increase in number in a limited area. The whole of the burnt ale cannot then be disposed of as food for cattle. At one time it was considerably used as a food for pigs. Some of the distilleries had large piggeries about the distilleries themselves, and considerable quantities of pot-ale were used. But the use of it for such purposes is limited; it does not contain a large enough percentage of nutrients, and it is very sour.

26875. And have these piggeries been given up?—Yes; so far as I know, almost entirely.

26876. Do you know why?—No, I do not.

26877. But where it can be so used it is a very useful food, is it not?—Up to a certain point. There is some difference of opinion upon that point. Most of those in the neighbourhood of distilleries who use it for cattle think that it is a useful food; on the other hand, a number of those who have tried it hold rather a different opinion. I know one gentleman in particular, a well-known farmer, who made some quite independent experiments with it, and came to the conclusion that it was rather harmful than useful.

26878. It is very acid, is it not?—Very acid.

26879. And that perhaps is a drawback?—That is a drawback no doubt. I think myself, judging from its composition and from the account given of it by various

persons who have used it, that it may have some sort of tonic and appetising properties. Just as certain meat extracts which contain a number of the breakdown products of proteid are tonic in their properties with human beings, or are held to be so, possibly it may have some properties of that kind with regard to animals.

26880. This pot-ale has a certain analogy with meat extracts, plus additional carbohydrates ?—Plus a considerable amount of acid, which I take it is largely lactic acid.

26881. Probably there are also a large number of acids ?—There are other acids present undoubtedly but I satisfied myself that there was a considerable amount of lactic acid at any rate.

26882. (*Sir William Ramsay.*) Do pigs like to eat it ?—They take it quite readily, and so do cattle, but I think it is a mistake from the cattle point of view to attempt, as some distilleries did, to make cattle consume very large quantities. Even if it were fed lukewarm, so that there was no great waste of heat, it would be uneconomical, if not injurious, to pass a great excess of liquid through the animal. It would cause excessive excretion of urine, and excessive nitrogenous waste.

26883. (*Sir Michael Foster.*) Then, its use as a manure is also limited by circumstances ?—Yes. Its use as a manure has started only comparatively recently, while its use as food is older. They apparently used it as food right back in the days when distilleries were very small, and they were able to dispose of the whole of it in that way. But I cannot find any evidence of its use as manure until comparatively recently, and there is still a very strong prejudice against its use as manure. There is a common idea that it sours and destroys the land, causes growth of fungus, and so forth. I take it that such opinions are derived from the fact that where it has been used it has generally been applied in excessive quantity.

26884. It has been used chiefly as a top dressing, has it not ?—Yes.

26885. (*Mr. Power.*) Has it been ploughed in at all ?—I have seen it placed on ploughed land. In one case they ran it through pipes and carried it over a considerable area of land, both ploughed and grass land.

26886. On the surface of the ploughed land ?—Yes. on the surface.

26887. (*Sir Michael Foster.*) But it has not been ploughed in ?—No, that is not necessary as it would naturally sink in and distribute itself through the soil.

26888. (*Mr. Power.*) It has not been covered in after distribution on the surface ?—No. I am of opinion that, generally speaking, distribution on the surface would be the most effective means of applying it to the land. Then its manurial constituents would be retained by the soil naturally.

26889. (*Sir Michael Foster.*) But it has a much greater analogy with farmyard manures than with the ordinary manufactured manures, phosphates, and so on. The usual method of using farmyard manure is to put it on the land and plough it in ?—Yes—but of course agricultural practice varies greatly as to methods of applying farmyard manure.

26890. But a very large quantity of farmyard manure is so used; it is put on the land and ploughed in ?—Yes. Farmyard manure, however, is mainly insoluble solid and requires to be mechanically mixed with the soil, while burnt ale is liquid, and will distribute itself.

26891. May one say that there has not been any very large amount of actual observation as to the proper way of using this pot-ale as manure ?—That is the case. There have been very few careful observations. I have endeavoured, in some cases, to get accurate observations made, but so far I have not succeeded in getting reliable experiments carried out.

26892. Another method of treatment is by evaporation, is it not ?—Yes.

26893. Either by simple evaporation, the reduction of the fluid to a mere syrupy condition, or evaporation followed by a process of drying, or what we may call torrefaction ?—Yes.

26894. Have you any statement to make with regard to those methods ?—The difficulty with regard to simple evaporation is that you cannot reduce burnt ale to a dry mass; it simply becomes a sticky paste, and mere evaporation by economical modern machinery will not take us further than a syrup. The use of such a syrup as manure would be very limited indeed, while for use as a food stuff it has the great disadvantage of containing a large percentage of acid. The percentage of acid, calculated as lactic acid, that I found in various samples, averaged about 10; the total non-volatile matters of the syrup would average 45 per cent. 45 per cent. of non-volatile matters with about 10 per cent. of lactic acid means a liquid so very sour as greatly to limit its applicability as a food stuff. (Appendix II. Table I.)

26895. When the evaporation is followed by this process of torrefaction, by which the material is brought into a pulverisable condition, fairly dry—what have you to say about it in that case ?—It is capable of use for manurial purposes, and is suitable for carriage and distribution through ordinary trade channels.

26896. And it has a very considerable value for manurial purposes, has it not ?—Yes. But a great disadvantage of the processes at present in use is that in torrefying or igniting it sufficiently to bring it into a pulverisable condition you lose nitrogen which, from a manurial point of view, is the most valuable constituent present. I have here a series of analyses of various products.

26897. You will put those in ?—Yes. These are analyses of products which have been prepared with the idea of putting them upon the market as manures, and the amount of nitrogen in them varies according to the extent to which they have been burnt. One sample contains under 1 per cent.—0·32 per cent. (Appendix II. Table IV.)

26898. From what distillery material was that sample ?—It was a Longmorn distillery sample.

26899. The samples you had from Tamdhu Distillery did they give you much less of nitrogen ?—They contained a considerable percentage of nitrogen. But I have not in this paper distinguished the distilleries from which they samples came. In some cases I do not know where they were from.

26900. (*Sir William Ramsay.*) What is the highest percentage ?—Over 8 per cent. The highest percentage I have here is 8·11.

26901. That nitrogen is lost during the process of torrefaction ?—There is no loss during evaporation; even a gentle scorching heat does not drive off the nitrogen. I believe the heating may be so great as to cause a considerable amount of decomposition and carbonisation before there is any appreciable loss of nitrogen.

26902. Would it not be possible to recover that nitrogen in the form of sulphate of ammonia ?—That is one of the things I was going to suggest. It should be possible to obtain all the ammonia by carrying over the gases evolved during the process of torrefaction, and absorbing them with sulphuric acid in suitable apparatus. The details of the process have not, so far as I am aware, been worked out. Such a process could only be carried out economically on a large scale. It would not do for small isolated distilleries, but where very large volumes of burnt ale could be treated it would probably prove more economical, so far as utilisation of nitrogen is concerned, than any process that I know of at present in use.

26903. (*Sir Michael Foster.*) You mean the process of evaporation, followed by torrefaction, with the additions that you have suggested ?—Yes. The nitrogen of the manure at present market prices is worth several times as much per unit as any other manurial constituent. as compared with phosphoric acid, for instance, the nitrogen would be worth about 13s. at a moderate estimate, as against 3s.

26904. Per hundredweight ?—No, per manurial unit, which is 1 per cent. per ton. Again, a unit of potash is worth 3s. 6d. or 4s. as against 13s. for nitrogen. A process, therefore, which retained the nitrogen would be most valuable. The objection to the torrefaction process is that it drives off a large proportion of the nitrogen. In the analyses I have put in the nitrogen varies from almost nothing up to nearly 9 per cent. I have found that samples which contained a large percentage of nitrogen were not in a fit condition to be put on the market

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as manure; they were still quite sticky, and therefore hardly fit to be made a marketable manure.

26905. You have great confidence that methods are possible by which this evaporation and torrefaction process can be carried on without that loss of nitrogen?—I have. In addition to the method mentioned already I have also suggested that burnt ale might be dried along with sulphuric acid. The resulting product, which would contain excess of sulphuric acid, could afterwards be treated with mineral phosphate. This would produce a good mixed manure in which part of the phosphate would be in water soluble condition. This is a mere suggestion, I have not been able to get trials made with the method.

26906. Or, at any rate, with a much diminished loss?—With a much diminished loss, at any rate.

26907. And that would make the process much more remunerative?—I think so. But I do not think that any process of this kind could be made one which would pay the distilleries.

26908. By utilising the heat from the flues might it cover the expense?—Possibly it might cover the expense or at any rate be less expensive than many of the systems distillers are trying. I take it they would need to work on a large scale to recover all the manurial value of the nitrogen as well as the phosphates and potash. There are large percentages of phosphates and potash as well as nitrogen in the burnt ale. The analyses in my table which have low nitrogen have high phosphates and potash. One which has only 0·32 of nitrogen has 17·12 of phosphoric acid and 16·33 of potash.

26909. With the retention of the nitrogen suggested by yourself the manure would really be a very valuable manure, would it not?—Yes, a manure of all round high value.

26910. (*Sir William Ramsay.*) Would not the sulphuric acid be reduced by the temperature which would be necessary to make the stuff powdery?—There would be action of that kind. There have been no experiments made on the subject, and I am not sure at what stage it would be advisable to add sulphuric acid. One could go to a considerable length with the heat before loss of nitrogen began.

26911. With sulphuric?—Without sulphuric.

26912. (*Sir Michael Foster.*) Then there is the bacterial method of treatment?—Yes.

26913. Mere filtration has always proved unsuccessful?—That is so.

26914. What have you to say about the bacterial method of treatment?—It can be made successful; and complete purification can be effected by means of it if sufficient area is allowed and sufficient aeration given

26915. Do you know the works at Mortlach?—Yes, I have seen those.

26916. They are fairly successful, are they not?—They have been worked so as to be fairly successful, I believe, but the amount of aeration required per unit of burnt ale is so great that any bacterial system for treating it must be very much more troublesome than a system for the treatment of a dilute liquid like ordinary sewage. I do not think enough attention has been given in such systems as I have seen to the question of aeration, the question of providing the maximum amount of air. The systems tried have all been on the contact principle, which supplies only a very limited amount of air.

26917. In the Mortlach system there is a final percolating filter which gives a good deal of aeration?—Yes, that was introduced later, I understand. I do not think I have seen that.

26918. That brings in the aeration that you require?—No doubt. But I think that an intermittent sprinkling system such as I suggested at a meeting at which Dr. Cowie was present is better and gives a greater amount of aeration per unit of space. I made experiments on a small scale, working with sprinkling filters, and got very efficient purification in that way. But the amount of liquid applied to such a sprinkling filter had to be strictly limited. After a certain point was passed the purification rapidly fell off and presently ceased. The quantity applied has to be very much less than in the case of ordinary sewage (Appendix II., Tables VII. and VIII.)

26919. (*Mr. Power.*) What material did you use for the filter?—Medium fine coke, with a little ordinary soil to infect it with the necessary organisms. In that case when only a comparatively small amount of burnt ale was applied, the quantity of nitrates which one could get through such a filter was very great indeed.

26920. (*Sir Michael Foster.*) Can you describe one of your experiments and state what the composition of your material was?—The effluent applied in the case of which I have the figures here was not a pure burnt ale. I had diluted the burnt ale with proportional quantities of all the other distillery effluents—spent lees, steep water, and so forth. (*See* Appendix II, Table VIII.)

26921. What was the composition of that?—After precipitation by lime, so as to remove material which was filtered off and worked up to make a by-product, the composition of one portion was as follows. Total solids were 1,069·0 per 100,000.

26922. This is before precipitation?—After precipitation, but before treatment on the bacterial filter. Total solids 1,069 per 100,000; loss on ignition, 910 parts per 100,000; total nitrogen, 42 parts per 100,000; free or saline ammonia, 3·2 parts per 100,000; and oxygen consumed 110·4.

26923. How did you treat that?—That was then sprinkled on a small tank filled with coke which had been inoculated originally by mixing a little soil on the surface and gradually brought into cultivation by dressing with this diluted burnt ale for a few weeks.

26924. What was the size of it?—Simply a 10 in. diameter zinc tank about 18 in. deep. The first effluent contained only 147 parts of solids as compared with over 1,000 to start with, of which sixty were lost on ignition, free ammonia 0·11 as compared with over three; oxygen consumed in four hours 0·660 as compared with 110, and the nitrate present 13·71. In this effluent so long as the quantity treated was comparatively small the nitrates were so plentiful in the effluent that they could easily be detected by ordinary laboratory tests. As the quantity was increased—I increased it until the dressing was equal to four gallons per square yard per day—the nitrates diminished though the effluent continued sweet, still contained nitrates, and did not undergo secondary putrefaction. When I increased the dressing to 5 gallons per square yard per day the nitrates fell off and ceased, and the effluent soon began to come through putrid. I attempted to give as much aeration as I could, but I do not think I had the maximum aeration I could have obtained by using a larger filter with artificial means of aerating it. The experiments were limited; I had merely very crude and insufficent means of carrying them out. (Appendix II., Table VIII.)

26925. Then as to the method by precipitation; I think you have made a number of experiments on that?—Yes. My idea is that if bacterial treatment is used at all it should be used along with precipitation treatment to remove as much as possible of the valuable constituents, especially of the burnt ale, before the effluents are passed on to the bacterial treatment. I think, considering the value from a manurial point of view of the by-product which can be obtained, it would pay to do so, first because you will get a by-product of a certain market value, and second, because you will render your effluent easier to treat afterwards; since you have removed a considerable part of the polluting materials from it. To begin with, burnt ale contains a considerable amount of matter in suspension which can be removed without any precipitation. That itself is a richly nitrogenous substance, largely consisting of yeast, and is a manurial material of considerable value. (Appendix I., Table III.) A great deal of it was allowed to go to waste about Speyside. There used to be tons and tons of it, the sludge which collected in the old filter beds lying about simply causing a nuisance. I obtained some samples of this sludge which was lying about rotting and dried them to a marketable condition. The analyses (Appendix II. Table III.) show that when dry it formed a valuable manure. It was easily dried to a marketable condition. I recommended the distillers to have it dried and marketed, but nothing was done. By adding lime to the burnt ale practically all the phosphate and a portion of the nitrogen in solution is precipitated. (Appendix II., Table V.) Therefore by adding lime till the ale is alkaline you obtain not only all the yeasty matter but in addition a consider-

able amount of valuable manurial matter which was originally in solution. Practically none of the potash is precipitated. The precipitate I found amounted to about 2 grammes per 100 c.c. of liquor, or practically 2 per cent. of the weight of the burnt ale that is treated. On the average it requires about ½ per cent. of lime of good quality to effect the precipitation. The precipitate settles readily and is easily filter-pressed. It can be dried by the waste heat of the flues and then forms a friable manure of which I have a number of analyses here.

26926. You will be able to put those in, with a statement of all the details ?—Yes. (Appendix II., Table VI.

26927. May we say that that process seemed to you to be a promising one ?—I think it is a very promising process.

26928. Precipitation enables you to get a considerable quantity of manurially valuable material, and at the same time facilitates purification by the bacterial process ?—And facilitates purification by the bacterial process. The effluents from the precipitation process should be allowed to undergo a preliminary process of decay in a septic tank, and should then be completely purified by treatment on intermittent bacterial filters with as great a degree of aeration as possible.

26929. (*Sir William Ramsay.*) Is there any difficulty in regulating the amount of lime you add ? I suppose it does not matter if you add a little too much ?—A little too much does no harm. At the same time it would require regulation, because the effluent has afterwards to be treated bacterially ; it is still very impure, and the lime if present in excess might interfere with that.

26930. (*Mr. Power.*) I am not quite clear whether you are dealing with pot-ale *per se*, or with a mixture ?—In my experiments I dealt with the pot-ale by itself in the precipitation process. For the bacterial purification I mixed the effluent from the precipitate with a corresponding proportion of spent lees, steep water, etc., and treated all these together. In addition to the burnt ale, it might be well to include the yeasty washings from the "backs" in the precipitation process, as this liquid contains a sediment of high manurial value. (Appendix I., Table VII.). It is not necessary to include lees or steep water in the precipitation process.

26931. You would propose to add these all the same ?—I propose to add them before treating bacterially.

26932. (*Sir William Ramsay.*) The first steep water is very dark coloured and very polluted. Is it proportionate to the strength, or do you think the first steeping takes out some matters which are more easily fermented than others ?—Partly. I find the first steep water varies very much. In three samples of which I have analyses here, one fermented very badly, and contained 0·493 grms. per 100 c.c. of solid matter. That was a turbid yellow liquid, and in two days was in a state of putrefaction. It was in the summer I got it, and it rapidly became stinking. The second sample contained only 0·066 of solid matter. In other words the total solid matter was only about one-eighth of the amount contained in the first sample. (Appendix I., Table V.)

26933. That is also a first steep ?—Yes, and also from foreign barley.

26934. (*Mr. Power.*) Was there any great difference in the amount of suspended matter in the two samples ?—I am speaking of the total solids. There was not a great difference in the amount of suspended solids in the two samples. The second also was a turbid yellow liquid, and of the total solids it contained 0·04 grm. per litre were suspended matters—0·04 out of a total of 0·066. It putrefied to a very small extent ; it had no smell, and it did not become foul on keeping. The third sample, which was from home barley, did not putrefy at all. I tested for phosphate in the ash, and found a little phosphate, especially in No. 1.

26935. Does anything lead you to believe that the fungus will grow only in the presence of phosphates ? Is it your experience that when the phosphate is excluded the fungus will not grow ?—I have no evidence of that, but as phosphorus is, so far as we know, an essential constituent of all organisms I should think it is probable that if phosphate is completely excluded the fungus will not grow. But I have really no experimental evidence on the point. I determined at one time the percentage of nitrogen in *Leptomitus*, and found, as is usual in fungi, that it is very high, I have no doubt it removes that nitrogen from the water. I did not determine quantitatively the amount of phosphate it contained, but a qualitative estimation showed that it was small.

26936. In the fungus ?—Yes. So that I take it it does not remove any very large amount from the water, because the amount it contains in itself is small.

26937. (*Sir Michael Foster.*) That small quantity may be very essential ?—Probably quite essential.

26938. (*Sir William Ramsay.*) I calculate that the figure you gave—13s. per unit—for the nitrogen works out at about £10 8s. per ton as sodium nitrate. Does it not sell at a much higher price ?—95 per cent. nitrate of soda costs at present about £11 per ton at the principal ports. That is the ordinary agricultural quality.

26939. Then you are taking a low figure ?—Yes, a low price. Even sulphate of ammonia would have a somewhat higher price per unit than I was calculating. I was taking approximately the price at which nitrogen would sell in such manures as bones.

26940. It would not pay to bring the pot-ale any distance to make it undergo this treatment for manufacturing manure ?—Not unless it could be carried at the very cheapest rate, say by gravitation in pipes.

26941. There is a possibility of doing that, is there not ?—Where there are a number of distilleries within a comparatively limited area it would be feasible to bring the pot-ale to a centre for treatment.

26942. Would you recommend that the distillers themselves should undertake this, or would it be a separate undertaking ? Would it pay anyone to get pot-ale from the distilleries, or to ask the distilleries for a small contribution ?—I do not think it would pay. As far as I hav been able to go into these matters I do not think that an process that I know of would pay in itself.

26943. That means that the distillers must do it to prevent a nuisance ?—I take it that certain processes in which the maximum by-products are recovered might pay, or nearly pay, all expenses if carried out economically on a fairly large scale, but I do not think they would leave a profit. It would not be worth while for a syndicate to take the matter up in the hope of making a profit

APPENDIX I.
COMPOSITION OF DISTILLERY EFLUENTS

TABLE I.
BURNT ALE: MATTER IN SOLUTION.

	Sample No. 1.	Sample No. 2.	Sample No. 3.
Specific gravity at 15° C.	1·018	1·013	1·016
	Grms. per 100 c.c.		
Total non-volatile matters	3·089	3·143	3·732
Ash	0·489	0·421	0·458
Total nitrogen	0·134	0·142	0·160
Albumenoid nitrogen	–	0·040	0·042
Phosphoric acid	0·188	0·167	0·131
Lime	–	–	0·015
Potash	0·141	0·132	0·174
Soda	–	0·009	0·066
Acidity as lactic acid	1·053	1·200	0·990

These samples were obtained from three different distilleries.

No. 1 contained, in addition to the solids in solution, 1·48 grms. per 100 c.c. of solids in suspension, or 4·569 grms. of total solids in solution and suspension.

The solids in solution, or, more correctly, the non-volatile matters in solution were determined by drying a thin layer in a steam oven. It is difficult to determine them accurately, as they lose the last of their water with difficulty, and if prolonged drying be resorted to, they alter in other respects.

The albumenoid nitrogen was determined by Stutzer's method with copper hydrate.

TABLE II.
COMPOSITION OF BURNT ALE.

	Sample No. 4.	Sample No. 5.	Sample No. 6.	Sample No. 7.
Specific gravity at 15° C.	1·018	1·019	1·017	1·019
	Grms. per 100 c.c.			
Solids in suspension	0·20	1·15	0·72	0·99
Non-volatile matters in solution.	4·04	3·67	3·62	3·57
Total non-volatile matters.	4·24	4·82	4·34	4·56
Total ash	0·43	0·40	0·39	0·49
Acidity as lactic acid	0·89	1·64	1·01	1·39

I have made examinations of burnt ale, more or less complete, from eight different distilleries. In no case did the total non-volatile matters fall below 4 per cent., or rise above 5 per cent. In several cases the samples were drawn by myself, and in all cases I endeavoured to secure a representative sample from a large bulk, generally a still charge. If the burnt ale is not well stirred up before the sample is drawn it is difficult to obtain an average proportion of the suspended matters.

TABLE III.
SUSPENDED MATTER OF BURNT ALE, DRY.

Total nitrogen	8·12	9·03
Albumenoid nitrogen	–	8·12
Ether extract	–	0·83
Ash	5·20	7·02
Phosphoric acid	0·52	2·26
Potash	0·15	0·60

This table gives analysis of the suspended solids from samples 1 and 2, Table I. These were filtered off and dried below 105° C.

The suspended matters of burnt ale consists mainly of the solids of the dead yeast. They form a sticky substance very difficult to filter from the liquid. They readily settle to a bulky sludge, and where this is allowed to accumulate, as in the settling tanks and filter beds of distilleries, it soon acquires the consistency of soft cheese. This substance putrefies readily, and soon becomes very offensive. It is highly nitrogenous, and consists largely of proteid matters.

TABLE IV.
SPENT LEES.

	No. 1.	No. 2.
Appearance	Opalescent.	Opalescent.
Specific gravity at 15° C.	0·9990	1·0013
	Grms. per 100 c.c.	
Acidity (as acetic acid)	0·037	0·043
Total solids	0·029	0·0189
Ash	0·014	0·0086
Containing copper	—	0·0032

No. 1.—The ash contained copper and traces of iron, calcium, phosphoric acid, and sulphuric acid.

No. 2 contained traces of various organic bodies, including alcohol and acetic acid.

It is sometimes stated that spent lees is a very noxious liquid, poisonous to vegetation and to fish.

The sample No. 1 was watered freely upon growing seedlings of various kinds, and also upon mature plants. and did them no apparent injury. Some oats and grass seeds were sown in pots and watered with another sample of spent lees for several weeks. During this time no other water was given. They germinated and developed to all appearance quite normally.

TABLE V.
STEEP WATER: FIRST STEEP.

	No. 1. American Barley.	No. 2. Foreign Barley.	No. 3. Home Barley.
Time in Steep	24 hours	24 hours	24 hours
Specific gravity at 15° C.	1·0030	—	1·0003
Reaction	Distinctly acid.	Distinctly alkaline.	Faintly acid.
	Grms. per 100 c.c.		
Total Solids	0·493	0·066	0·0092
Ash	0·240	0·037	0·0016
Nitrogen	0·0174	0·0026	—
Albumenoids (N × 6·25)	0·109	0·016	—

No. 1 was a turbid yellow liquid. It was two days old when received, and was already beginning to putrefy. (The weather was warm.) It rapidly became stinking. The ash contained the usual ash constituents of plants, and was rich in phosphates.

No. 2 was a turbid yellow liquid. It contained solids in suspension, 0·040 grm. per litre. It had no smell and did not putrefy on keeping.

None of the samples gave any reaction with iodine.

These samples illustrate the great variation in the composition of this liquid. No. 1 is probably exceptionally badly polluted. No. 3, on the other hand, is exceptionally slightly polluted for a first steep water.

WASHINGS FROM "BACKS."

A sample of the washing from the "backs" as nearly representative of the bulk as I could obtain, was a turbid grey liquid which frothed a little on shaking. It putrefied on keeping. It had a sour yeasty small, and a slightly acid reaction. It contained in grms. per 100 c.c. :—

TABLE VI.

Solids in suspension	0·0582
„ solution	0·0372
Total ash	0·0090
„ nitrogen	0·0072
Albumenoids (N. × 6¼)	0·0450

In the case of another sample, the solids in suspension were allowed to settle. They were then removed and dried. They gave the following analysis :—

TABLE VII.

	Per Cent.
Moisture	3·01
Organic matter	85·19
Phosphoric acid (P_2O_5)	3·42
Lime	5·06
Potash	0·61
Containing nitrogen	6·71

The liquid was slightly alkaline, from the lime added in lime-washing the backs. As the analysis shows, this sediment is a substance of considerable manurial value.

NITROGENOUS MATTERS IN SOLUTION IN BURNT ALE.

TABLE VIII.

SYRUP FROM BURNT ALE, NO. 2 (TABLE I.)—NITROGEN IN NITROGENOUS MATTERS.

	Per cent.
Total nitrogen	1·99
Of which there was contained in—	
Proteids, salted out by zinc sulphate	0·65
Peptones, precipitated by phospho-tungstic acid	0·19
Amido compounds	0·14
Ammonium compounds	0·15
Undetermined compounds, by difference	0·86

BURNT ALE, NO. 3 (TABLE I.).

	Grms. per 100 c.c.
Total nitrogen	0·160
Of which there was contained in—	
Proteids, salted out by zinc sulphate	0·033
Peptones, precipitated by phospho-tungstic acid	0·053
Amido compounds	0·015
Ammonium compounds	0·009
Compounds, undetermined: by difference	0·050
„ „ by actual determination	0·053

In the above table the nitrogen in ammonium compounds was determined by distillation with magnesia. Bodies such as asparagine, yield half their nitrogen as ammonia on boiling with dilute mineral acid. The nitrogen of bodies of this kind, which I call *amido* nitrogen, was estimated by boiling for one hour with 5 per cent. sulphuric acid under a reflux condenser, distilling with magnesia, and doubling the nitrogen so found after subtracting that originally present in ammonium compounds.

The nitrogenous matters of burnt ale are very complicated. The soluble nitrogenous matters extracted from malt have been extensively studied by others, and are known to be very complicated. These are then altered in the mash tub and in the fermenting vats by action of proteolytic ferments from the malt and by living ferments. The resulting liquid, which, as we have seen, contains a considerable amount of acid, is then subjected to a prolonged process of hydrolysis in the stills. The resulting burnt ale contains, as we might expect, nitrogenous matters of all degrees of complication, from proteids down to ammonium compounds. The solids of burnt ale are, as shown already, very rich in nitrogenous matters. These are the most important matters contained in the burnt ale, whether we look at it as a putrefying and polluting material, or as a material to be utilised as food or manure. In the matters in suspension the amount of nitrogen is so great that, as shown in Table III., about half of the suspended matter must consist of nitrogenous substances. These nitrogenous bodies are almost entirely proteids precipitated by copper hydrate.

Burnt ale contains in solution about 0·15 per cent. of nitrogen. Multiplying this by the factor ordinarily used in food analysis, 6¼, we find 0·94 per cent., or nearly 1 per cent., of nitrogenous matters. Proteid reagents, however, precipitate only a fraction of this nitrogen. The larger portion is contained in decomposition products of the proteids.

A series of experiments was made with the syrup from Burnt Ale No. 2 (Table I.), which was treated with various re-agents which precipitate proteids.

The results are tabulated, in percentages of nitrogen precipitated, as follows :—

Experiment No. 1.

	Per Cent.
Copper hydrate in excess	0·84
In the filtrate from this, phospho tungstic acid	0·12

Experiment No. 2.

Copper hydrate in excess	0·81
In the filtrate from this, tannin	0·11

Experiment No. 3.

Phospho tungstic acid in excess	0·74
In the filtrate from this, tannin	0·11

Experiment No. 4.

Tannin in excess	0.66
In the filtrate, phospho tungstic acid	0·15

Experiment No. 5.

Milk of lime, till quite alkaline	0·27
In the filtrate, phospho tungstic acid	0·56

In every case where tannin was used it was difficult to say when precipitation was complete. After adding excess of tannin and removing the precipitate, the filtrate always deposited more precipitate. In one case, other work called me away, and some tannin precipitations stood covered for four months. They were then filtered, and after filtration the clear filtrates were allowed to stand a few days. Further precipitation then gradually took place.

APPENDIX II.

COMPOSITION OF BY-PRODUCTS FROM BURNT ALE AND DISPOSAL EFFLUENTS.

Table I.

Composition of Burnt Ale Syrup.

	1.	2.	3.	4.	5.	6.	7.
Moisture	29·51	68·75	53·59	56·83	52·50	48·80	47·32
Nitrogenous matters (N × 6·25)	16·75	10·69	14·56	11·25	14·81	12·50	13·19
Acid as Lactic acid	21·51	4·36	10·12	3·76	8·77	12·07	10·02
Other substances, by difference	23·77	11·89	16·03	22·78	17·32	20·46	23·74
Ash	8·46	4·31	5·70	5·38	6·60	6·17	5·73
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Albumenoids (Stutzer's method)	—	7·13	9·56	7·50	9·56	6·94	6·38

No. 1. Prepared by open pan evaporation from burnt ale after removal of yeasty sediment.

No. 2. Prepared by open pan evaporation, whole burnt ale including yeasty sediment boiled down to $\frac{1}{10}$th of its original bulk. It contained Solids in Suspension 10·63 per cent., Solids in Solution 20·65 per cent.

Nos. 3, 4, 5, 6, and 7 were prepared from whole burnt ale, including yeasty sediment, by evaporation in multiple effect vacuum evaporating plant. No. 4 contained :—

Nitrogen - - - 1·80 per cent.—equal to Ammonia 2·19 per cent.
Lime - - - - 0·12 „ „
Phosphoric acid - - 2·00 „ „ „ „ Tribasic Phosphate of Lime 4·36 per cent.
Potash - - - - 1·75 „ „

Table II.

Burnt Ale and Draff Feeding Cake.

	1.	2.	3.
Moisture	16·33	11·47	12·57
Oil	3·50	2·90	5·94
Nitrogenous matters	18·50	18·50	22·11
Soluble Carbohydrates, &c.	48·94	56·76	36·04
Fibre	8·48	5·97	8·83
Acid as lactic acid	—	—	7·56
Ash	4·25	4·40	6·95
Siliceous matter	0·77	0·87	1·30

These cakes were prepared by mixing dried distillery draff and burnt ale syrup together and pressing the product into cake by hydraulic presses. In No. 3 a little cotton-seed meal was added to improve the composition and to prevent the mixture sticking to the plates in the press.

Sludge Obtained from Distillery Filtering Ponds.

This sludge consisted of the solid matters in suspension in burnt ale which settled to the bottom of the filtering ponds which were formerly used at Speyside distilleries.

The accumulation of this sludge, in a more or less offensive condition, has caused much trouble about distilleries. A distillery mashing 2,000 bushels a week would, I estimate, produce a little over a ton of dry sludge per week, equal to about five tons wet. In some cases this has been disposed of in the wet state to farmers, but it is difficult to handle in this state, on account of its stickiness, and farmers are suspicious of it as a strange substance of unknown value, and because in some cases where it was used it did harm rather than good. Such unfavourable results were probably due to over-application of so nitrogenous a manure, and to imperfect distribution on account of its sticky nature. In other cases considerable expense and trouble were incurred in burying it, or in deodorising it by means of antiseptics to keep down the nuisance. If it had been roughly dried, I have no doubt it would have commanded a market as manure. Organic nitrogenous bodies which contain a good percentage of nitrogen, and decompose readily, command a high price in the manure market. The rich odour of the partially decomposed substance would not have been a serious disadvantage for this purpose.

I obtained some samples of this strong-smelling decomposing material which was being allowed to go to waste. The analyses of three samples are given in Table III.

Table III.

Distillery Sludge, Dry.

	1.	2.	3.
Organic matter	65·05	80·72	75·02
Containing nitrogen	5·71	8·56	7·00
Ash	34·95	19·28	24·98
Containing:			
Phosphoric acid	3·54	2·02	2·25
Potash	—	0·28	—
Silicious matter	23·42	12·09	17·71
Equal to tricalcium phosphate	7·72	4·41	4·91

No. 1 was taken from a large sample prepared by spreading out the sludge, and drying it in the sun. Roughly dried in this way until fit to bear carriage it contained 23·26 per cent. of moisture.

The ash of each sample is made up largely of sandy matter. This is derived from the shallow sandy ponds in which the sludge was allowed to settle. With a little care this sand could easily be excluded. This would increase the value of the sludge as manure.

TABLE IV.

MANURE PRODUCTS PREPARED FROM BURNT ALE.

———	1.	2.	3.	4.	5.	6.	7
Moisture	6·47	3·16	4·28	14·53	4·03	—	—
Organic matter and carbon	78·19	29·37	6·68	45·15	66·15	—	—
Lime (Ca.O)	0·23	1·27	1·10	—	—	—	—
Potash (K_2O)	3·28	15·19	16·33	1·88	1·09	0·83	6·75
Phosphoric acid (P_2O_5)	3·91	19·60	17·12	4·99	3·92	5·00	12·15
Siliceous matter	0·76	2·95	3·87	25·92	19·50	2·56	—
Containing nitrogen	4·39	2·13	0·32	2·89	8·11	3·77	4·39
Equal to ammonia	5·37	2·58	0·39	3·44	9·85	4·57	5·33
Equal to tribasic phosphate of lime	8·55	42·79	37·38	10·89	8·56	10·92	26·53

Nos. 1 and 2 and 3 were all prepared from whole burnt ale, which was first concentrated in mutiple effect evaporators. No. 1 was then heated to charring in an oven, and consisted of a dry, black, coal-like material. No. 2 was burnt to ash in a furnace. The ash contained a good deal of black cinder containing much carbon. No. 3 was burnt to ash in a rotary furnace, which had been previously used in soda recovery. It contained over one-third of its weight of carbonate of soda derived from the furnace. It contained 6·46 per cent. of phosphoric acid, and all its potash in a water soluble condition.

Nos. 4 and 5 were prepared from whole burnt ale by the use of "waste heat" from the flues behind the stills. No. 4 was a sticky substance with a sour charred smell. No. 5 was a dry charred substance in appearance, like cinders.

No. 6.—Black charred substance. A little sticky.

No. 7.—A rather sticky powder, apparently consisting of charred burnt ale. It contained phosphoric acid soluble in water 2·60 per cent.

LIME PRECIPITATES OF BURNT ALE.

Lime preciptates a certain amount of the dissolved nitrogenous matter of burnt ale. It also precipitates almost the whole of the phosphates, as well as some other matters. Burnt ale, No. 1, Table I., Appendix I., after removal of the suspended matters, was made slightly alkaline with milk of lime. The precipitate formed amounted, when dried, to a little over 10 grms. per litre. It was a light-coloured brittle substance which was readily dried and powdered.

It contained when dry :—

TABLE V.

	Per cent.
Organic matter	45·25
Phosphates, as tricalcium phosphate	35·75
Potash	0·20
Containing nitrogen	2·17

The whole burnt ale, including its suspended matter, when rendered slightly alkaline by lime, gives a heavy grey flocculent deposit, containing both the suspended matter and the precipitate. This can be filtered, or filter-pressed, much more readily than the suspended matter alone. It dries easily to a crisp grey solid which is easily powdered. On the average it requires about ½ per cent. of lime of good quality, or fifty pounds of lime per 1,000 gallons, to effect this precipitation.

The following table gives analyses of some samples obtained in this way, dried to marketable condition.

TABLE VI.

PRECIPITATE BY LIME FROM BURNT ALE.

———	1.	2.	3.	4.	5.	Mean.
Grms. obtained per 100 c.c.	1·2	2·5	3·6	1·7	—	2·25
Moisture	5·35	12·40	6·18	11·27	9·46	8·93
Organic matter	66·20	56·15	74·25	52·39	58·03	61·40
Phosphates, as tricalcium phosphate	23·32	16·20	11·07	20·11	17·60	17·66
Potash	0·79	0·95	—	—	—	0 87
Lime	—	—	—	16·28	17 68	16·98
Containing nitrogen	4·98	4·13	5 80	4·03	4 78	4·74

Nos. 1, 2 and 3 were samples prepared on a small scale in the laboratory. Nos. 4 and 5 were prepared on a larger scale at distilleries. They are, therefore, probably the most representative samples. No. 4 was filtered through a sack. No. 5 was filter-pressed.

The filtrate after this treatment is still a very impure liquid, and is quite unfit to be turned into any water-course. The above treatment is not suggested, therefore, as a means of getting rid of the pollution, but merely as a means of getting something of value out of the burnt ale, and at the same time taking a first step in the purification, by removing all the suspended and a part of the dissolved solids. The filtrate is dark in colour, and froths very badly on shaking. Even when diluted with 100 times its volume of water it still froths. If allowed to stand it soon begins to putrefy, and after a time stinks badly. It contains on the average nearly as much non-volatile matter in solution as untreated burnt ale. For, though we have removed a certain amount of solid matter, this is compensated for by the lime which has been added, and by the volatile acid which has been fixed as salt. It contains on the average about half as much nitrogen as untreated burnt ale with the suspended matter included, that is, about 0·12 grm. per 100 c.c. It contains very little phosphate, but nearly all the potash of the original liquid. It is, therefore, still a liquid of high manurial value, and has still a very much greater polluting power than ordinary sewage.

Even when diluted with the spent lees and the other waste liquids of the distillery, the mixture is still a very noxious effluent. Mixtures of this kind, prepared from the filtrate of burnt ale after the lime treatment, mixed with spent lees, steep water, and wash-up water, all freed from any suspended matter, and mixed together in the calculated average proportions in which they are produced at the distilleries, were prepared for experiments on further purification by bacterial treatment. The following table gives analysis of two such mixtures.

Table VII.

Mixture for Bacterial Treatment.

——	1.	2.
	Parts per 100,000.	
Total solids	1,069·0	1,350·0
Loss on ignition	910·0	1,140·0
Total nitrogen, Kjeldahl method	42·0	45·9
Free or saline ammonia	3·2	5·9
Oxygen consumed in four hours	110·4	Very great, over 100.
Chlorine	—	15·9.

These liquids contain more than ten times as much solid matter in solution, and six or seven times as much combined nitrogen in solution as an ordinary sample of town sewage. They also show enormously greater oxygen absorption from permanganate than sewage.

This mixture putrefies readily. It contains nothing to inhibit or diminish the activity of the micro-organisms which cause decay, but, on the contrary, contains just the sort of matter in which they flourish freely. In this it resembles sewage, and is dissimilar to many trade effluents, which are injurious to bacteria. This is, therefore, a liquid which should be suitable for treatment by irrigation, or by bacterial beds or filters.

A small experimental filter bed was treated daily for a period of about eight months with gradually increasing quantities of these mixtures. In Table VIII. analyses of samples of the effluents are given. The mixtures were sprinkled on the bed intermittently.

Table VIII.

Effluents from Bacterial Treatment.

——	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
		Parts per 100,000.			
Total solids	147·20	108·00	149·00	180·00	244·00
Loss on ignition	60·00	40·00	23·00	24·00	54·00
Free or saline ammonia	0·011	0·027	0·029	0·048	0·057
Albumenoid ammonia	0·067	0·092	0·144	0·209	0·440
Oxygen consumed in four hours	0·660	0·88	1·13	1·89	3·22
Nitrogen in nitrates	13·71	4·50	4·64	1·93	Absent.

Sample No. 1 in this table is an effluent from the period when the mixture was being applied at the rate of 1½ gallons per square yard. During this period the nitrates reached their maximum. In some cases they were found to be as great as 20 parts of nitric nitrogen per 100,000. As the dressing increased they fell away. Apparently when the amount of organic matter increases beyond a certain point much denitrification takes place in the bed. In no case was more than a fraction of the combined nitrogen applied to the bed recovered in the combined nitrogen of the effluent.

The dressing was then increased to about 2 gallons per square yard per day, given six days a week. This was continued for about two months. The mixture used at this time was No. 1, Table VII.

The analysis of the purified effluent obtained during this period is No. 2. The dressing was then increased to three gallons per square yard per day, added in three dressings daily. The mixure used for this period was No. 2, Table VII. The analysis of the purified effluent is No. 3. After this had been continued a few weeks the dressing was increased to the rate of 4 gallons per square yard per day, and then to the rate of 5 gallons per square yard per day. During both these periods the application was made in four dressings daily. The analyses of the effluents for these periods are Nos. 4 and 5. In the last of these we have reached the limit of the capacity of the bed. After the application at the rate of 5 gallons had been continued for four days nitrates ceased to appear in the effluent. A few days later the effluent began to smell a little. The experiment was then discontinued. It had lasted altogether eight months.

Mr. Stevenson Macadam, F.I.C., F.C.S., called in; and Examined.

Mr. Stevenson Macadam, F.I.C., F.C.S.

8 Feb. 1906.

26944. (*Chairman.*) As far as I am concerned I merely ask you whether you will be good enough to allow us to print the statement you have supplied in our evidence; a proof will be sent to you for correction?—Certainly.

I am a Fellow of the Institute of Chemistry of Great Britain, of the Chemical Society of London, of the Society of Public Analysts, London, and of the Association of Public Analysts of Scotland.

I am Public Analyst for a number of counties and burghs, and hold other appointments which bring me in contact with questions concerning the disposal of waste products, including sewage and manufacturing effluents.

For many years I assisted in the work connected with the carrying out of the North Esk Agreement, which exists between His Grace the Duke of Buccleuch and the manufacturers on the River North Esk (Midlothian), and I was ultimately appointed arbiter under that agreement. No distilleries come within the scope of this agreement, but it has afforded me considerable opportunity of studying the effect of settlement, precipitation, filtration, and incineration on waste polluting liquids as applied on a large and practical scale.

I was first actively engaged in the special question of distillery pollution about the year 1897, and I have been more or less interested in the subject since then.

Immediately before the date mentioned an extensive increase took place in the Scotch distilling industry, which naturally led to a large increase in the waste products, and these were, as formerly, in major part, passed direct into the nearest stream without any attempt at purification. Matters went from bad to worse until it became necessary for the riparian proprietors to establish their rights at law, and several cases have since occupied the attention of the Scotch Courts, and I have been connected with some of these.

In the preparation of whisky a large quantity of water is employed, and only a small proportion is ultimately retained within the distillery. The major part is discharged as waste product, and is highly polluting.

The process of making whisky may be roughly divided into four stages:—

1. Steeping of the barley in chests, or tanks of water.
2. Malting and drying of the steeped barley.
3. Infusion and fermentation of the barley.
4. Distillation of the fermented liquid.

Stage 1. *Steeping of the Barley.*

This operation is performed by placing the barley in chests or tanks, and covering it with ordinary water. After the water has remained in contact with the barley for a given time it is run off to waste and a fresh supply added.

A third treatment, and sometimes a fourth, is given, and the "steeping" is finished. During the process the barley absorbs a quantity of water equal to approximately one-fifth of what is added, and it loses to the water certain soluble mineral salts, and organic bodies, as well as any dirt, or grit, which is attached to or diffused through the barley corns. The liquid is usually of a dirty grey appearance, and is highly polluting, as the following results will show.

Analyses of Barley Steep Waters.

	Grains.		
Grains in imperial gallon:			
Saline and earthy matter	138·40	to	59·04
Organic and volatile matter	127·68	„	52·00
Total solid matter	266·08	„	111·04
Of which in solution:			
Saline matter	113·44	„	46·56
Organic and volatile matter	106·56	„	48·32
Total solid matter	220·00	„	94·88
Of which in suspension:			
Saline and earthy matter	24·96	„	12·48
Organic and volatile matter	21·12	„	3·68
Total solid matter	46·08	„	16·16
Chlorine	20·65	„	7·48
Acidity as lactic acid	667·20	„	44·48
In million parts:			
Free and saline ammonia	20·50	„	10·00
Albuminoid ammonia	67·00	„	25·00

Mr. Stevenson Macadam, F.I.C., F.C.S.

8 Feb. 1906.

The barley steep water is prone to rapid putrefaction, and from the considerable proportion of potash salts and phosphates, it is well suited for the propagation of the low forms of fungoid growths which accompany distillery pollution.

Stages 2 and 3. Malting and Drying of the Steeped Barley, and Infusion of the Barley.

These stages do not directly produce polluting liquids, but they are responsible for a considerable share of the polluting matter contained in the general washing waters. The quantity and quality of such waters varies greatly in every distillery, but the following figures may be taken as fairly representative :—

Analysis of Washing Waters.

——	Grains.
Grains in imperial gallon :	
Saline and earthy matter	17·60
Organic and volatile matter	92·80
Total solid matter	110·40
Of which in solution :	
Saline matter	14·72
Organic and volatile matter	19·52
Total solid matter	34·24
Of which in suspension :	
Saline and earthy matter	2·88
Organic and volatile matter	73·28
Total solid matter	76·16
Chlorine	2·80
Acidity as lactic acid	6·40
In million parts :	
Free and saline ammonia	11·00
Albuminoid ammonia	123·00

Stage 4. Distillation of the Fermented Liquid.

At this stage three liquids are produced, viz. :—

A. Burnt ale or pot ale.
B. Spent lees.
C. Alcohol.

The burnt ale and spent lees constitute the residues which are left in the stills after the distillation and redistillation of the fermented barley liquid. They are waste liquids which are run out of the stills after the distillations have ceased, and constitute a part of the general distillery refuse. The alcohol leaves the still as vapour, and after condensation it is received in the spirit receiver, and ultimately reaches the market as whisky.

The average composition of burnt ale may be gathered from the following analysis.

Analysis of Burnt Ale or Pot Ale.

——	Grains.
Grains in imperial gallon :	
Saline and earthy matter	312·00
Organic and volatile matter	2603·20
Total solid matter	2915·20
Of which in solution :	
Saline matter	297·60
Organic and volatile matter	1857·20
Total solid matter	2154·80
Of which in suspension :	
Saline and earthy matter	14·40
Organic and volatile matter	746·00
Total solid matter	760·40
Chlorine	90·10
Acidity as lactic acid	667·20
In million parts :	
Free and saline ammonia	170·00
Albuminoid ammonia	1200·00

Burnt ale, or pot ale, as its name implies, is an ale, but it is minus alcohol, and unhopped. It is a heavy, brown, organic liquid, and in its fresh state of not unpleasant smell. It contains a considerable proportion of the mineral salts of the barley, and is usually accompanied by a quantity of matter in mechanical suspension. It is a highly putrescible liquid, and can be best described as an excellent broth, or culture medium, for the lower forms of life.

The spent lees are left as a residue in the second still, and are not so polluting as the preceding liquids. Their general composition may be taken as follows :—

Analysis of Spent Lees.

——	Grains.
Grains in imperial gallon :	
Saline and earthy matter	13·12
Organic and volatile matter	16·32
Total solid matter	29·44
Of which in solution :	
Saline matter	11·68
Organic and volatile matte	14·08
Total solid matter	25·76
Of which in suspension :	
Saline and earthy matter	1·44
Organic and volatile matter	2·24
Total solid matter	3·68

ANALYSIS OF SPENT LEES—*cont.*

	Grains.
Chlorine	0·94
Acidity as lactic acid	44·80
In million parts:	
Free and saline ammonia	1·40
Albuminoid ammonia	2·32

The acidity is volatile, and is most likely entirely acetic acid, but it is calculated as lactic acid for comparison with the other liquids. Copper is a common constituent of spent lees, and I have found as much as 1·85 grains in the imperial gallon when calculated as metallic copper. Though any proportion likely to be found would be quickly lost in any reasonable body of water, the effect on a domestic supply might be serious.

The relative proportions of the different liquids produced varies, but will in most cases approximate to the following, for each bushel of barley used:—

	Gallons.
Barley steep water	18·12
Burnt ale	13·12
Spent lees	3·75
Washing waters	12·50
Spirit	2·25
	49·74

In other words, each gallon of spirit made produces 21·11 gallons of waste liquid. Taking a distillery using, say, 2,000 bushels of barley per week it will have to treat practically 95,000 gallons, or 424 tons of waste products, and will manufacture 4,500 gallons of spirit.

There can be no doubt that the most polluting liquid, and the one most difficult to manipulate is the burnt ale. In former times it was the practice for the distilleries to keep cattle, or pigs, or both, on the premises for the purpose of consuming the burnt ale which forms a nutritious drink, and is consumed by animals with apparent relish. A certain portion was also applied to the land, and formed a useful liquid manure. It was, and I understand still is, freely given to neighbouring farmers for similar purposes. While the distilleries were of a reasonable size and output, a great part of the burnt ale was disposed of in such a manner, and any excess when discharged with the other polluting liquids was in a new and fresh state. Apparently little inconvenience was experienced from what then passed away, and I attribute this to the limited quantity, especially of burnt ale, and to the fresh condition of the liquids. Not only did the pollution increase with the extra production of spirit, but apparently the custom of keeping cattle began to die out. I have frequently seen the cattle sheds falling into more or less disrepair, but I do not remember ever seeing any cattle in them. The custom of supplying neighbours with such burnt ale as they will take still continues, but the quantity so disposed of is very limited, and for practical purposes may be neglected.

I have rarely seen burnt ale applied to land, and I do not think the practice is very general. In any case, its use must be restricted to certain periods of the year, and the quantity applied must be within limits.

When fresh distillery waste is discharged into a considerable body of fresh running water, I am of opinion that it has little tendency to form fungoid growths, or objectionable glut. It has, however, a marked tendency to produce persistent froth, and I attribute this in most part to the burnt ale. As a salmon and trout angler I have no hesitation in saying that the fishing will suffer to a very great extent from such. Should the burnt ale enter into partial decomposition before it reaches the stream, it is certain to produce vast beds of the distinctive distillery fungus (Opodya lactea or Leptomitus lacteus). This body is a low form of vegetable growth which spreads rapidly, and not only covers the bottom of streams with a heavy slimy deposit, but is constantly floating down in detached masses. It may be found in all stages of healthy and vigorous growth, and of decay, and putrefaction. When fresh it is most unsightly to the eye, and when decomposing it is equally objectionable to the senses of sight and smell. Beyond rendering the water within its influence quite unfit for primary purposes, it seriously interferes with healthy fish life. The detached masses disturb the fish both in pool and on spawning bed, and lead to a loss in sport and reproduction. The abundant growths are usually to be found in the shallower and quieter streams, such as form the natural spawning beds in a river. The presence of the fungus will either deter the fish from making use of such stretches for the spawning purposes, or it will materially influence the hatching of the spawn from the choking of the beds. The abstraction of the dissolved oxygen from the water by the fungus, and the substitution of poisonous gases instead, is a point of very considerable importance when considering the healthy life of fish, and the destruction of healthy vegetable growths, and the various forms of larva and insect life need only be referred to.

Anything approaching a satisfactory solution of the difficulty of rendering distillery refuse innoxious has not, in my opinion, been arrived at, and the laboratory experiments which I have made have not been attended with success.

Evaporation and Incineration of Burnt Ale.

Everything, in my mind, points in incineration as the only solution, but the process is costly, and is attended by some trouble. The burnt ale produces a pretty hard carbon which is difficult to consume, and at high temperatures the potash salts tend to fuse to glasses. The first practical attempt at incineration was tried at Benrinnes Distillery, situated in the Aberlour district of the Spey. About the year 1899 attempt was made to consume the burnt ale by spraying it up the distillery chimney, where it met the waste heat from the still fires, and was resolved into an ash, which collected in the flue, and could be removed when necessary. It was claimed at the time to be a complete success, but very shortly it was found that the masonry work of the chimney was becoming seriously damaged, and the process was stopped. I had not an opportunity of testing the power of incineration, but I remember I did not credit the statements which were made regarding it. It was a good practical experiment, however, and the ash obtained was in first-class condition for handling as a manure. I made an analysis of an average sample of the ash, and I obtained the following proportions in 100 parts by weight:—

ANALYSIS OF BURNT ALE ASH FROM BENRINNES DISTILLERY CHIMNEY EXPERIMENS. JULY, 1899.

	Per cent.
Insoluble silica	6·68
Soluble silica	1·56
Oxide of iron	1·90
Alumina	1·10
Lime	22·08
Magnesia	0·43
Potash	17·02
Carried forward	

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ANALYSIS OF BURNT ALE ASH—*continued.*

	Per cent.
Carried forward - - -	
Soda - - - - - - - -	2·90
Oxide of copper - - - - -	0·11
Soluble phosphoric acid - - - -	0·64
Insoluble phosphoric acid - - -	18·69
Chlorine - - - - - - - -	0·30
Sulphuric anhydride - - - -	1·10
Moisture - - - - - - - -	18·06
Organic matter - - - - - -	5·64
Carbonic anhydride, etc. - - - -	1·79
	100·00

The foregoing results demonstrate that the mineral residue left from the burnt ale is of first-class manurial quality, and worth about £5 3s. per ton.

More recently it has been claimed that it is possible to evaporate the whole of the burnt ale produced in a distillery, by the distilleries' own waste heat, but I doubt this very much. The matter is of great importance, and should form the subject of careful and thorough investigation.

Suggestions have been made to evaporate the burnt ale and manipulate the residue as a cattle food. I have no faith in such a scheme. The evaporation must be conducted in such a manner as will prevent charring of the organic matters, and this necessitates steam heat. The most successful experiments that I know of in this direction were made by heating the burnt ale by means of revolving spiral steam pipes. The rate of evaporation to commence with was reasonable, but ultimately the tendency was for the material to "felt" on to the pipes, and practically stop the passage of the heat. In any such scheme the acidity of the burnt ale, and its tendency to putrefactive decomposition must be remembered.

Feeding cakes manufactured by incorporating such materials as wet grains, with the burnt ale, have nothing to recommend them. An analysis of such a cake gave the following results:—

	Per cent.
Moisture - - - - - - -	17·85
Oil - - - - - - - -	2·20
Albuminoids - - - - -	21·22
Starch, gum, sugar, &c. - - -	46·43
Woody fibre - - - - - -	6·90
Ash - - - - - - - -	5·40
	100·00
Acidity as lactic acid - - - -	2·47

The acidity is objectionable, and the keeping properties very limited.

In any system of evaporation the abstraction of water from neighbouring streams may become a serious question. In a distillery working 2,000 bushels a week, the burnt ale alone means a loss of 26,240 gallons, or 117 tons of water, and if the other liquids are similarly treated the abstraction of water will be enormously increased.

Distribution of Burnt Ale on Land as a Manure.

This method of disposing of burnt ale has been long in use, but the practice in recent years has apparently decreased. Burnt ale is undoubtedly a good liquid manure when applied at the proper time, and in proper quantity. It is usual to sprinkle it as a top dresser by means of barrel or tank carts, and this is done in the early season when the crop is beginning to come away, and again in the autumn to encourage the growth of grass in the stubble. Over-application leads to burning of the young shoots, and the quantity applied must therefore be limited in amount. I have seen old strong pasture completely burned up, and rotted, in places where the burnt ale had, by natural circumstances, accumulated in undue proportion. The total quantity which can be disposed of in this manner is comparatively trifling, and during the greater part of the period which a distillery works the burnt ale is not required. Its use is also restricted to a small area surrounding the supply.

Treated as Sewage by Irrigation.

Attempts to treat burnt ale by ordinary irrigation on land, either alone, or along with domestic sewage, have been found useless. I first witnessed this at Macallan Distillery on Spey-side, where attempts were made to purify the distillery waste by distributing it over an area of land after much of the suspended matter had been allowed to settle in ponds. The ground selected was in many respects well suited for such an experiment, though it had not undergone any preparation. The distillery was situated on a flat at some considerable elevation, and at some distance from the River Spey. It was anticipated that by the time the liquid had percolated down through the high bank and through the fields below that it would be rendered harmless, but such was not the case. The liquid issued in a highly putrid and offensive condition which gave rise to gross pollution of the river, and produced vast quantities of the usual fungus. The pollution ultimately became the subject of the action of Seafield *v.* Kemp, in the Court of Session, Edinburgh, in January, 1898.

I observed similar results when inspecting the Dailuaine-Glenlivet Distillery in 1899. For several years this distillery had been passing its refuse down to ponds situated in a haugh adjoining the Spey. There was no outlet from the ponds, and they were separated from the river by a considerable extent of somewhat sandy and gravelly land. The liquid from the ponds gradually filtered through this, and when it reached the river so little purification had taken place that extensive pollution was noticeable for a long distance below. This matter also came before the Scotch Courts.

In 1900 Messrs. Geo. Cowie & Sons, of Mortlach Distillery, Dufftown, endeavoured to compel the Police Commissioners to give them access to the public sewers for the distillery waste. The Commissioners were at the time preparing to treat the town sewage on a sewage farm, and they objected to take over the refuse from the distillery on the ground that it would injure the sewer pipes, and would prejudicially affect the disposal of the sewage by sale, or application to land. The position of the Commissioners was upheld by the First Division of the Court of Session, in December, 1900.

During the course of this inquiry I visited, among other places, the town of Rothes, where they were endeavouring to treat the refuse from the neighbouring distilleries along with the town sewage. The process employed was to first treat the inflowing mixture with alum and lime, and to afterwards settle, and filter through ash beds. The effluent from the filter beds was then distributed over land, and the discharge passed to the Spey. I found the works in hopeless disorder, and practically serving no useful purpose. The liquid leaving the filters was little better than when it entered the works, and the irrigation ground was completely covered and choked with beds of distillery fungus in all stages of growth and putrefaction. The liquid merely passed over the surface, and discharged into the river. The track of the liquid was clearly marked by a continuous bed of fungus and glut, which covered the bottom of the stream for a long distance below.

With a view of ascertaining the probable action of distillery effluents on the cement joints of pipes, I visited the North British Distillery, Edinburgh, and examined the cement work connected with the dreg storage tanks.

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These tanks are constructed of brick, laid in a mixture of one part of cement to three parts of sand, and are "grouted" over with the same material. I found the binding to be quite soft and sandy, and it could be easily removed by a knife. An analysis of a portion gave the following composition in 100 parts by weight :—

	Per cent.
Insoluble silica	81·06
Soluble „	2·44
Oxide of iron	2·14
Alumina	5·66
Lime	0·15
Magnesia	0·08
Alkaline salts	0·62
Sulphuric anhydride	0·16
Chlorine	0·03
Organic matter	5·26
Moisture	2·40
	100·00

The organic acids of the dreg had dissolved away practically all the lime, and left little else than sand.

Each tank had an air shaft formed of ordinary glazed drain pipes, joined with pure cement, which was within the influence of the dreg. I found again that the cement was destroyed, and quite friable. I readily removed a portion and obtained the following results on analysis.

For comparison I also give the analysis of an ordinary cement :—

	Ordinary Cement.	Cement acted on by Dreg.
	Per cent.	Per cent.
Insoluble Silica	1·10	69·84
Soluble Silica	22·02	2·92
Oxide of Iron	4·09	2·26
Alumina	7·75	3·31
Lime	61·68	0·04
Magnesia	1·14	0·01
Alkaline Salts	0·16	0·70
Sulphuric Anhydride	1·24	0·04
Chlorine	—	Trace
Organic Matter	0·48	17·72
Moisture	03·4	316
	100·00	100·00

An average sample of the dreg showed an acidity equal to 276 grains per gallon, when calculated as lactic acid.

Precipitation by Chemicals, and Mechanical Filtration.

The effect of such general precipitants as alum and lime on distillery refuse are disappointing. This was observed on a working scale at Rothes Sewage Farm, and laboratory experiments corroborated the fact, as the following series of results with burnt ale will show :—

	Original burnt ale.	Treated with 100 grains of alum per gall.	Treated with 100 grains of lime per gall.	Treated with 100 grains alum and 100 grains lime per gall.
Grains in imperial gallon :				
Saline matter	312·00 gr.	356·96 gr.	359·60 gr.	402·40 gr.
Organic and volatile matter	2,603·20 „	1,842·40 „	1,850·40 „	1,845·60 „
Total solid matter	2,915·20 gr.	2199·36 gr.	2,210·00 gr.	2,248·00 gr.
Acidity as lactic acid	667·20 gr.	—	—	—

Treatment by neutralisation with chalk, lime water, etc., are equally unsuccessful, either when the mixture is allowed to settle, or when it is passed through a mechanical filter composed of such materials as sand, ashes, or fresh or charred peat. A considerable quantity of the colour may be removed under favourable circumstances, and more especially if the burnt ale is previously somewhat diluted with water, but the effluent remains highly nitrogenous, polluting, and prone to active decomposition.

Bacteriological Methods.

Bacterial beds give reasonable promise of something reliable in the future, if applied in treating the less offensive distillery liquids, but I have not myself had the opportunity of establishing their power of dealing with such liquids as undiluted distillery waste, even when previously settled. Many claims have been made for different systems, which I am afraid are not borne out by actual authentic and continuous experiment. I have myself conducted no experiments in this direction.

STEVENSON MACADAM.

26945. (*Sir Michael Foster.*) In this memorandum you take rather an unfavourable view of all the processes ?—Yes, except that of evaporation.

26946. With regard to treatment on land, the success of that would depend upon the quantity of land available in the immediate neighbourhood ?—Yes.

26947. And perhaps also on the method by which it was applied ?—Yes, and, of course, the nature of the land.

26948. It is generally applied as a top dressing, is it not ?—Yes.

26949. Has it been used to be ploughed in in the way one applies any farmyard manure ?—Not that I know of.

26950. Do you think an adequate number of observations have been made as to how far this can be utilised with care on the land ?—I think so, yes.

26951. You think that all is known that can be known as to the use of it ?—I think so. You see there are such enormous bulks of it, and the carrying comes to a very considerable item.

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26952. I was speaking rather as to the way in which it should be applied to the land in order to get the best results without injury to the land?—Quite. I think that has been fully gone into.

26953. Then with regard to the method of incineration; that you think is the best method?—I think it is the only method.

26954. Is that complete incineration, or the process that is adopted in several places which does not go any further than what we may call torrefaction, where a pulverisable mass is produced?—I think that is far enough to go. There are certain advantages in only carrying it to that length.

26955. That, in your opinion, is the present best method?—I think it is the only method.

26956. Of dealing with the burnt ale alone or of all the other matters?—I think that need only apply to burnt ale.

26957. That is, evaporation to a certain extent, and then the thickened material is exposed to heat, so as to produce a black pulverisable mass?—Quite.

26958. By that means a very considerable quantity of nitrogen is lost?—Yes.

26959. And that you would neglect?—That we must neglect.

26960. Could it not be recovered in any way?—I am afraid not—not to pay.

26961. Can this process of evaporation and torrefaction be carried on so as to pay?—I am afraid not. I have made some calculations as to that, and I am afraid it cannot be carried on so as to pay.

26962. Can it be carried on so as to cover expenses?—I am afraid not.

26963. Not even when the waste heat of the flues is utilised?—It might come down to something like paying itself then. But in my calculations I have not had the opportunity of knowing what waste heat from distilleries might be utilised, and I have never included it; I have put in the cost of fuel.

26964. Then as to the method by bacterial treatment. You regard that unfavourably?—Yes.

26965. Do you know the process adopted at Mortlach by Messrs. Cowie & Co., where they first of all precipitate the suspended matter, then put the clarified fluid on the contact beds, ending with a percolating filter? It is said to produce an effluent very near the Mersey and Irwell standard?—Yes, I have heard of it, but I do not know the process; I have not seen it working. But there has always been very considerable doubt as to what was going in at one end of the filter and what was coming out at the other.

26966. Have you considered a process by which a good deal of suspended matter and some other things are removed by precipitation, phosphates and so on, thus producing a precipitant which is a fairly valuable manure?—Yes.

26967. And also rendering the remainder very much more amenable to bacteriological treatment?—I have, but that is not my opinion.

26968. You still think unfavourably of that system?—Yes, of the effluents from that treatment.

26969. Generally, it is evaporation and torrefaction that you think is the method that ought to be adopted?—There is a great deal of loss by that means, when you come to calculate it out with a modern plant. I have calculated it out in different ways, and I find that to produce a ton of ash——

26970. By "ash" you mean friable black material; there is a good deal of organic matter still left in it?—Yes, it is not a pure ash. It comes to about £6 calculated on one basis—from £6 to £6 5s.—to recover a ton of ash. Or you may look at it in another way. A great deal depends on the expense of fuel and on the heat value of the fuel you use. Using poor dross it may run from £6 6s. to £8 4s.; using better coal I calculate it runs to from £6 8s. to £7 7s.; so that you get an average of about £6 or £7. I calculate the ash to be worth about £5, so that it would mean the loss of £1 or so. But the way I look at it you will only have to produce about one ton of ash per week for a 4,000 bushel distillery, which is a big one; so that the whole expenditure would be about £6 or £7, and you would get about £5 for your material. Hence it would only cost you about £1 per week, without taking into account interest, depreciation, and interest on capital.

26971. (*Sir William Ramsay.*) Supposing the ammonia were recovered that would increase the value, would it not?—Yes.

26972. Is it not possible by means of sulphuric acid?—You see you have not the bulk.

26973. That is another question. Would it not be possible to bring the pot ale from a number of works to one centre?—If it was possible to concentrate a number of distilleries into one the cost would be very much decreased.

26974. Might it be done by pipes, perhaps?—Yes.

26975. If you are going to incinerate, it would not matter whether it were really fresh or a little putrid?—If they were collected it would have to be at a centre where you could get a number of distilleries, as they are doing on the Spey just now. I think that one machine would do for the whole lot. But really my difficulty there, is that you have such a lot of water in this material. There is such a lot of water to evaporate before you get the solid residue that you run away with a tremendous amount of heat. You must put in a pretty good machine, and the difficulty is to get a very good machine of small enough size to deal with the quantity.

26976. From a single work?—Yes. If you collected it, and kept the machine running night and day, keeping up the maximum feed, you would do it very much cheaper.

26977. The ammonia would make a difference of two or three pounds in the price, would it not?—It is the most valuable constituent, and it is worth 10s. a unit, while the constituent next in value, potash, is worth about 3s, and you have phosphates which I take at about 1s. or 1s. 3d.

26978. I understand that the amount of nitrogen in the pot ale is something like 13 or 14 per cent?—I have no analyses of that.

26979. If anything like that amount could be retained in it, the price would obviously be very much greater?—You increase a constituent which has three times the value of the next most important one.

26980. So that there would be a prospect of its paying if the products of various works could be brought to one spot?—I am afraid it would not be practicable, but that would be the result if it could be done.

26981. You mean lack of agreement between proprietors?—Besides, many of the distilleries are very isolated.

26982. Another point which you mention in your excellent proof of evidence is as regards barley steep waters. You say there is a considerable amount of phosphates present, and that therefore it is well suited for the propagation of the low forms of fungoid growths. Have you made any practical observations to show that such fungoid growths will not live unless there are phosphates present? We have been told so, and that is why I ask you?—I am afraid I cannot say that. That is my general information, but I cannot swear to it.

26983. You have not any proof of it?—No.

26984. Another point I made a note of there is the fact that there is a considerable amount of metallic copper in the pot ale?—There may be; sometimes it is entirely absent.

26985. Does that come from the stills?—Yes.

26986. (*Colonel Harding.*) You have expressed a strong preference for the system of evaporation?—Yes.

26987. Have you formed any opinion as to the best method of dealing with steep and wash waters? Do you think they require treatment?—Yes.

26988. What sort of treatment seems to you to be the best?—The best treatment I think is to add lime and allow them to settle. Then I would treat the effluent from that very much like sewage. Taking the effluent from that I would treat it by broad irrigation or intermittent filtration on land.

26989. Or probably, by bacterial beds?—I am rather unfavourable to bacterial beds from what I have seen in practice. The bacterial beds would remove the residue

of the organic matter, but they would not have very much effect on your potash or your phosphates, they would pass through, and they would still be included for the propagation of any form of life afterwards. I think the best way to dispose of it is to distribute it on land, grow a crop on it, and let the crop absorb the phosphates, and you get practically land drainage.

26990. That is not always practicable on account of the levels, is it?—It might not be, but it might be made practicable almost everywhere; it would be a question of pumping, and that again would lead to expense. But these distilleries are generally situated in country districts and are surrounded by land reasonably available for such purposes.

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Mr. F. Wallis Stoddart, F.I.C., F.C.S., called; and Examined.

26991. (*Chairman.*) I have only to ask you whether we may print this statement of yours in our evidence and have it on the Minutes of the Commission? A proof will be sent you for correction?—Yes.

Mr. F. Wallis Stoddart, F.I.C., F.C.S.

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The information I have to lay before the Royal Commission relates to the treatment of sewage in tanks as a preliminary to its application to filters, and consists of a statement of the results of certain experiments instituted primarily with the object of ascertaining whether improvement could be effected in the removal of suspended solids without having recourse to the use of chemical precipitants. That sewage can be satisfactorily treated, so far as its liquid and dissolved constituents are concerned, by simple application to a natural or artificial oxidising bed is, I think, clearly proved by recorded experiences on both the small and large scales; but that some method of removing the suspended solids before filtration is necessary, and that the effect of filtration is more perfect the more complete the removal of the solids appears to be equally plain.

Under the impression that the septic tank effected the desired separation of solids, I carried out some experiments at Exeter in the winter of 1898 with the permission and co-operation of Messrs. Cameron, Commin & Martin. The filter used was an elementary form of the Continuous Filter, the medium however being a fine breeze, which speedily became choked with the suspended solids contained in the tank effluent; and appreciating that no improvement in this respect could be looked for, the experiment was abandoned, my time being occupied with the construction of the filter. I was able to return to the question of tanking in 1903, and at first employed a submerged clinker bed, as this had been favourably reported on by various experimenters, and in one case at least within my knowledge was giving good results, though a considerable amount of offence was occasioned.

As earlier experiments had shown the impracticability of maintaining an upward flow in beds of this kind owing to accumulation of solids at the base, in this instance the liquid was made to pass horizontally through a bed of clinker graded from three inches to one inch in the direction of flow. The experiment was started in March and abandoned in the following September, as it was found impossible to produce as good results as with a simple tank of the same size, the liquid produced being by no means devoid of solids, but being highly offensive and comparatively insusceptible to the oxidising process, whilst a very luxuriant growth of sewage fungus took place at the outlet. These phenomena, the cause of which was not very clear at the time, were abundantly explained by later experiments.

A tank was then constructed with three submerged walls alternating with scum boards, the intention being to produce an undulating flow, and so to encourage the deposition of solids in the compartments. A clarifier, consisting of a bed of clinker one foot thick, was placed at the outlet end. The inlet was a submerged T pipe, and the outlet was a simple sill. The net capacity of this tank was 4,385 gallons, and the quantity of dry weather sewage passed through it per diem was 5,000 gallons. This tank acted extremely well, and in its main features was identical with that now in use; but as a result of watching its performance it was decided (1) that the submerged inlet was a disadvantage, as it produced a disturbance at the point at which the sewage entered the tank, driving the deposit forward; (2) that the clarifier was ineffective, as it became so clogged with growth that the passage of liquid took place at one or two points only; and (3) that a good deal of trouble arose in the filter from the floating up of masses of deposit, and the detachment of matter from the under surface of the scum, the solids from both sources travelling forward with the current, and ultimately passing out upon the filter. These observations were confirmed at the installation at Knowle, where there were two distinct tanks worked in series. It was there found that when the second tank was fairly clean, so that no great amount of fermentative action was going on, and it acted merely as a settling tank for solids coming forward from the first, much better results were obtained than when septic changes were going on vigorously in both.

It was thought that it would be better to raise the submerged walls to a level as near the surface as possible with a view to intercepting these floating masses of solids.

About this time I began to make systematic inspections of a variety of sewage works, in some cases opening up filter beds of different types that had become more or less ineffective, and was struck with the close similarity between the deposit which coated the medium, even where no tank was used, and that which could be seen passing away from the tank under observation. This deposit is obviously not sewage solids, nor the simply exhausted residue of such solids after digestion, because it consists very largely of substances not present in the original sewage at all, prominent amongst them being a gelatinous ferrous sulphide, plainly a most unsuitable substratum on which to develop oxidising organisms. It was noted, further, on comparing the features of the works inspected, that the production of this deposit, which occurred in widely different appliances, such as septic tanks and contact beds, agreeing only in sharing the "holding up" principle, was very closely connected with the length of time the sewage was detained in a stagnant condition, and was coincident with the disengagement of offensive odours when the resulting liquid was exposed.

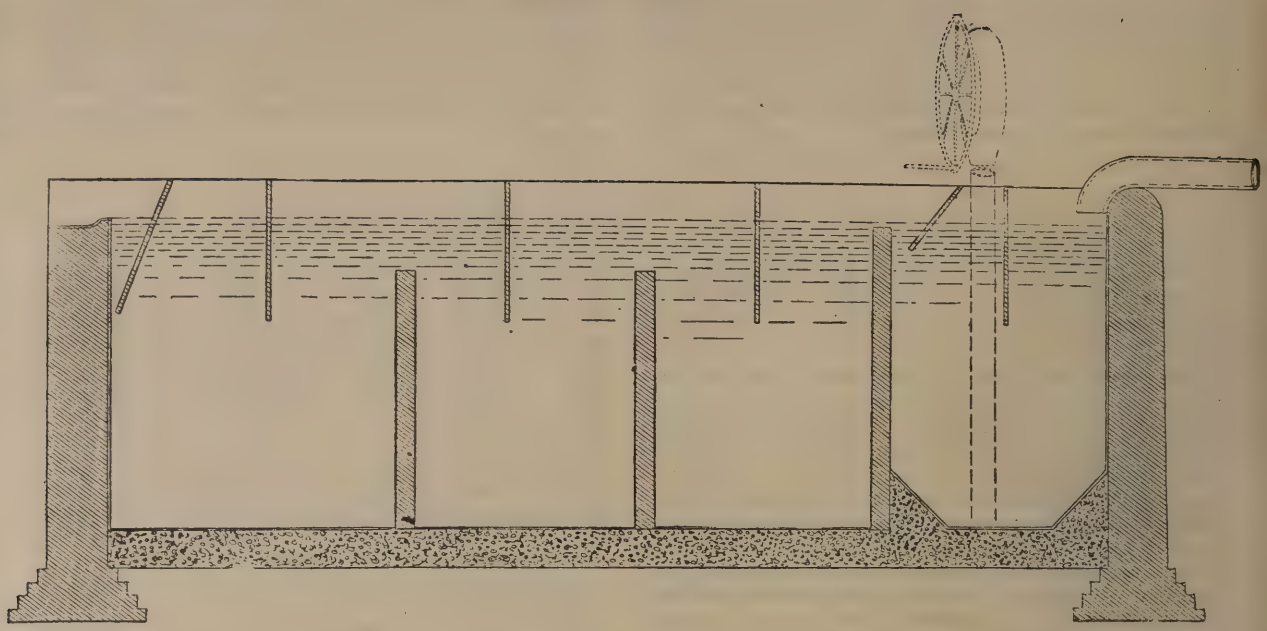
The subdivision of the experimental tank already described allowed also of the observation of the character of the deposit in the successive compartments, and it was seen that whereas the material in the first resembled in appearance precipitation sludge, and was not markedly offensive, that in the last consisted of the black deposit, and was much greater in amount than might have been anticipated, being sometimes indeed more than in the earlier compartments.

All these observations pointed to the common origin of the objectionable phenomena in excessive putrefaction, and to the inadvisability of detaining the sewage longer in the purification plant than is necessary to free it sufficiently from suspended solids; and I was so impressed by the absolutely imperative necessity of preventing the diffusion of offensive odours and the formation of secondary deposits, that I was inclined to think that it would be profitable to partly forego if necessary the advantages of the destruction of sewage solids by septic action, if by accelerating the treatment this result could be reached. A second tank of 5,000 gallons capacity was therefore constructed and completed on June 21st, 1904, for the purpose of observing the effect of different rates of flow. It differed from the first tank in having the inlet three inches above the surface of the liquid, in the absence of a clarifier, and in having the free margins of the walls and scumboards nearer the surface. The older tank, which had become sludged up to a depth of thirty-two inches in nine months, was altered to match, and both presented the construction shown in the section produced.

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SECTION OF TANK.



These tanks were then used at constant rates of flow from one tankful per diem upwards, and it was found that whilst with a rate of two capacities and upwards no evidence of over-putrefaction was observed, very little, if any, difference in the rate of accumulation of solids or in the effectiveness of the total treatment by tank and filter could be detected up to a daily flow of 15,000 gallons, or three capacities; but that at 32,000 gallons or six capacities sludge began to accumulate faster, and the filtrate began to deteriorate, whilst at 45,000 gallons or nine capacities, when the tank effluent contained between forty and fifty parts of suspended solids per 100,000, the appearance of the filtrate was such that it could not be considered satisfactory, although it is interesting to note that nitrification was even then well marked.

These experiments were defective in one respect, namely, that the gradually increasing deposit of sludge and diminution of tank capacity rendered the conditions less favourable as they progressed, that is as the higher rates of flow were reached. This was not appreciated at the time, and it would be of great interest to repeat the observations with a tank kept at constant capacity; unfortunately the imminent closure of the works renders this impossible.

Whilst then the acceleration of the tank treatment up to the point of a daily flow equal to three times the capacity of the tank was found not to involve the accumulation of a greater quantity of sludge, the diminished degree of putrefaction was found to do away entirely with offensive odour, with the formation of scum and of secondary products. Up to this point all the experiments had been conducted with a constant rate of flow; and the next step was to arrange a tank to be fed at the naturally variable rate. As the increase above average dry weather flow at the most active time of day is about 50 per cent. and it did not seem desirable that the rate at such times should much exceed three capacities per day, it was decided to feed the tank daily with a quantity of dry weather sewage, namely, 10,000 gallons, equal to twice its capacity and to allow diluted sewage up to 30,000 gallons per day to enter the tank during rain.

This quantity was taken by a bye-pass from a box of 100 gallons capacity, the contents of which were kept in a constant state of agitation by the discharge of the sewer into it, so that the sewage treated fairly represented in all respects the bulk of that brought to the works for treatment.

One other modification in working was introduced.

The first experiments in which the quantity of sewage tanked per day was, in accordance with the usual practice, equal to the capacity of the tank, had resulted in sludging up the latter in nine months to an extent which interfered with efficient clarification. This is perhaps a shorter period than is observed with sewages of less concentrated character than that at Horfield; but experience at Knowle and elsewhere goes to show that with ordinary domestic sewage the tank becomes so full of deposit in from twelve to fifteen months as to cease to perform its functions satisfactorily. Not only is the net capacity of the tank materially diminished, but larger and larger quantities of deposit begin to pass away with the tank effluent, and interfere with the efficiency of the filter attached. The process of cleaning out the tank being an unpleasant and troublesome one, it is frequently unduly postponed.

It seemed preferable, therefore, to arrange for the withdrawal at short intervals of smaller quantities of sludge and it was decided in the final experiment to remove the contents of the first compartment when necessary, for which purpose a chain pump was fixed in position, and a small plot of ground was trenched to receive the sludge.

One of the tanks then was cleaned out and started to work on November 18th, 1904. On December 22nd—thirty-four days later—sludge had accumulated in the first compartment to a depth of nearly five feet, and being pumped out measured 135 cubic feet. After this the sludge was pumped regularly from the first compartment monthly, and has measured on the average 125 cubic feet. There has been a small quantity of sludge in the second compartment from the early stages of the experiment, but it has not increased, and the third and fourth compartments are perfectly clean after the lapse of fourteen months. The depth of sludge has been measured most satisfactorily by a system of pointed cups arranged in spiral fashion upon a rod at intervals of an inch. This instrument is placed vertically in the tank, left for five minutes and withdrawn, when an exact record of the depth of sludge, and samples at all depths are obtained.

The dry solid matter removed per month represents about 20 per cent. of the raw sewage solids; it is by no means offensive and, as it contains an appreciable quantity of nitrogen and phosphates, can be beneficially applied as a manure.

The tank effluent contains on the average fourteen parts per 100,000 of suspended solids, and varies in this respect from eight to twenty parts. It is consistently free from smell, and from the other evidences of putrefaction. About the middle of August the tank assumed the usual septic appearance, a firm scum forming on the surface, and the effluent becoming of a dark colour, though there was no appreciable amount of black deposit in the channels. It was found that, owing partly to continued drought and partly to the temporary withdrawal of troops, the quantity of sewage had fallen and the quantity actually passing through the experimental tank was only 6,000 gallons per day. On opening the bye-pass to admit more sewage all the indications of over putrefaction disappeared except the scum which, though much thinned and broken, has not entirely vanished. I am of opinion therefore that the appearance of a true bacterial scum is the first indication of over-putrefaction, and that by maintaining the rate of flow through the tank at a point which falls just short of permitting this development the most common and forcible objection to the establishment of sewage works, namely, the diffusion of offensive odours,

can be entirely obviated, whilst the efficiency of the works as a whole will be distinctly promoted.

But whilst this presents no serious difficulty when dealing with the sewage of a population of a certain size, the extreme variations in the output of very small populations of a dozen persons or so render the adjustment a matter of considerable difficulty. So much so indeed that whilst I am convinced the efficiency of these works can be advanced by a proper regulation of tank capacity, I am inclined to doubt whether the production of offensive smells can always, and under all conditions be prevented by these means. Fortunately this is easy to effect on the small scale by enclosing the entire plant, and arranging a through current of air from the outlet of the filter through the latter and the tank to a suitable ventilating pipe. In this way not only is smell prevented but the necessary conditions for the proper purification of the sewage are observed.

In the course of these experiments two observations were made as to the rate at which sewage sludge will disappear in situ in the tank if left to itself. In the first case the depth of sludge diminished from thirty-two to nineteen inches—a reduction of 40·6 per cent. in three months; and in the second case from forty-four inches to thirteen inches, a reduction of 70 per cent. in twelve months. It was hoped that the destruction would be so complete that by providing alternative tanks it would be possible to dispose of practically the entire sludge in this simple way, but the results did not encourage this idea. In the second of these experiments the tank was underdrained to a valve in order that, after syphoning off the top water, the sludge might be drained, but the residue was too tenacious to be treated in this way.

26992. (*Sir Michael Foster.*) Your view is that the septic tank leads to such conditions as produce that black tenacious stuff which clogs up the filter ?—Yes.

26993. Have you any idea of what that is and how it is brought about ?—It is unquestionably precipitated from solution by the inter-action of sulphides and carbonates resulting from the change in the sewage with the iron and other elements present in the sewage in solution. I am speaking of the black material which deposits in the later part of the tank and on the particles of the medium in the filter, but I am not speaking of what are commonly called blacks coming away from the coarse continuous filter.

26994. (*Sir William Ramsay.*) Have you any analyses of the sludge of tanks in which the septic action has not been thorough or has not gone on to the ordinary extent ? In what way does the composition of the sludge differ from the sludge in tanks which are run for much shorter periods ?—Chiefly in the presence of ferrous sulphide in considerable quantities.

26995. What becomes of the sulphuric compounds; are they not decomposed at that stage—there are sulphates reduced to sulphides ?—Yes.

26996. I suppose that is theory ?—That is theory, yes.

26997. But the reduction does take place ?—Yes.

26998. Is that owing to the organisms not being there or not having time ?—Both to some extent, I think.

26999. (*Sir Michael Foster.*) Would not some sulphide come from organic matter ?—Of course, sulphide may be derived from organic solids, but I think the bulk of the sulphide is the result of simple reduction of sulphate. It is a difficult matter to prove absolutely, of course.

27000 (*Sir William Ramsay.*) I notice that in your pamphlet you say: "Precisely the series of phenomena described may often be observed where sewage is discharged into running water. Immediately adjacent to the outfall there is a deposit of sewage solids and a luxuriant growth of sewage fungus but no marked discolouration or offensive odour. Further down stream, and often separated from the outfall by a perceptible interval, the black deposits and offensive odours, popularly attributed to the sewage itself, but really due to the products of its decomposition, are to be observed." Can you give us instances of any spots where that has been noticed ?—It was very noticeable in the water course at Knowle before the establishment of the works in 1899; it is no longer there, because the works have been done away with.

27001. I merely wanted to know where it had been observed ?—That is the instance I had in my mind when I wrote that paragraph.

27002. Why is it objectionable that a septic tank should cover itself with a thick bacterial scum ?—Because mechanical troubles result from the detachment of the under surface of the scum, the particles detached passing on with the flow and lodging in the upper part of the filter. That is my chief objection to it.

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27003. The coverings I have seen have been very compact, tough sorts of coverings. But you think they are constantly detaching pieces from the lower surface ?—The lower surface is anything but compact. With a tough scum it is quite easy to cut a sample with a spade, which will be perfectly firm on the upper part, but when it is withdrawn from the liquid it is generally found to have a number of long filaments which break away. It is impossible to remove the sample of scum without leaving behind in the water stringy particles detached from the under-surface.

27004. Which are constantly being taken away by the flow and deposited in the filter ?—Yes.

27005. You make a remark as to opalescence which is rather striking. You speak of feeding the tank at a constant rate with dry weather sewage, and you say: "At thirty to thirty-five gallons per cubic foot (five to six capacities) the filtrate began to deteriorate, as shown by the appearance in the filtrate of the persistent opalescence characteristic of sewage and tank effluent, whilst at fifty-six gallons (nine capacities) the filtrate was hardly distinguishable in appearance from tank-effluent, although there was still a fairly strong nitrification. This opalescence is perhaps the most valuable of the rapid tests for final effluent, as its appearance invariably indicates the approaching breakdown of the filter." That is very interesting; but what kind of instances have you to show that this opalescence means the breakdown of the filter ?—"Breakdown" is perhaps ambiguous. I mean that the filter is becoming over-taxed with the quantity of liquid applied. All tank effluents, so far as I know, with the exception of one or two very completely clarified chemical effluents, have this persistent opalescence which refuses to clear if the liquid is allowed to stand for twenty-four hours. In a good filter effluent, in my opinion, there should be nothing of that sort; there should be solids in suspension, but they should completely clear rapidly. If a filter is treated with gradually increasing quantities of tank effluent one arrives at a point at which the final filtrate refuses to clear rapidly; the coarse particles which are still present do subside, but there remain in suspension very minute solid particles which give this opalescence. Directly that appears it seems to me that the tank effluent is going through insufficiently treated, and that view is supported by the ordinary details of analyses, when we find the analyses of the filtrate deteriorate in other respects. A final filtrate showing a little of this opalescence may be imputrescible, but when you are brought to a point at which it begins to be putrescible then I say it is a rough and ready indication of the condition of the effluent.

27006. That is colloidal matter in suspension, I suppose, which would otherwise be affected by the filter ?—It is matter in suspension; I should hesitate about calling it "colloidal."

27007. Have you any theory as to whether the substance in such suspension is attacked by passage through the filter or whether it requires to be in solution first ?—I have no absolute proof either way, but my impression very strongly is that this finely divided suspended matter is intercepted by adhesion to the filter, and is there either destroyed or converted by the living organisms in the filter, so that it no longer appears in the final effluent in the shape in which it arrived in the filter.

27008. You mean that it is converted into soluble compounds ?—I am speaking rather theoretically now, because I cannot advance experiments in proof. I think it is part of the feeding of the living organisms in the filter; if it is applied in reasonable quantities it is broken up and converted, and no longer appears in the shape in which it appeared in the filter. I do not think the suspended solids in the tank effluent should pass through a filter in good condition in the state in which they are applied to the filter at all. An almost corresponding amount by weight may pass away from a filter in good working order, but it must be entirely altered in constitution; microscopically it is entirely different; the solid deposit from the filtrate is entirely different in character; although it may be almost equal

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in amount to the suspended solids applied with the tank effluent. I think the finely divided matters probably adhere to the particles of medium very much as in the case of the sand filters of the water companies, although the thing is worked on rather a different system, and that the organisms actually live upon them together with the constituents of the sewage. The organisms forming this scum upon the particles of the filter undoubtedly do shred away, because microscopically we find that particles which come away with the final filtrate are identical with matters which you can scrape off the particles of the clinker in the filter in good working order. You get infusoria of a great number of types, organisms which are altogether absent from the incoming solids, and which are presumably being developed upon them.

27009. Have you ever examined the opalescent liquid microscopically?—Frequently.

27010. Can you see the particles?—You see a great number of bacteria, but you are doubtful how far the opalescence is due to bacteria or to other matter.

27011. (*Colonel Harding.*) In the first compartment of your settlement tanks you must necessarily obtain a scum which is formed largely of light matters floating on the surface?—Yes.

27012. You draw a distinction between that and what you speak of as bacterial scum?—Yes.

27013. What is, in your view, a bacterial scum?—It is a very complex matter, but it is largely formed of new growth, of filamentous fungoid growth, growing upon and living upon the sewage. The scum which forms in the first compartment consists largely of corks, match-sticks, fruit-skins, and other matters obviously introduced as such with the sewage.

27014. But you speak with dissatisfaction of the formation of a bacterial scum, and I wanted to find out exactly what was the difference between your bacterial scum and this—I am afraid—unavoidable scum which arises in the early part of the tank?—The difference is that the bacterial scum is a growth in the tank, formed only after the sewage has remained in the tank for some time. The longer the sewage has remained in the tank the thicker and the more voluminous is the bacterial scum. If the sewage is passed at a sufficiently rapid rate through the tank, the bacterial scum does not form. I object to the bacterial scum chiefly on mechanical grounds—the difficulty it introduces into the filter. I look upon the scum as an indication that the process of resolution is approaching offensive putrefaction. I do not so much object to the scum from its unsightly appearance, but I object to the offensive smells from the tanks, and as far as my experience goes the time of offensive smells is approaching when the scum becomes well developed.

27015. Why do you call it bacterial?—I am afraid I have taken that from reading the name by which it is generally known. I think everybody recognises the bacterial scum of a septic tank. It is quite true that bacteria form only a small part of it probably, but it is a very complex growth.

27016. You look upon it as an evidence of having reached or of being about to reach the putrefactive stage?—Yes, precisely.

27017. There is an evolution of gas in the deposits at the bottom, and this development of gas probably raises particles to the surface; is it the evolution of gas that you deprecate?—No. I do deprecate the formation of gas for other reasons. The evolution of bubbles of gas obviously disturbs very much the contents of the tank, and prevents the object of the tank.

27018. Suggesting as you do that the accumulations may and do remain for many months, can you avoid the evolution of gas? If the liquid passing through is not putrefactive, surely the deposits in the tank which remain for many months—twelve months as you suggest—must become putrefactive?—My proposal is not to allow the deposits to remain for anything like as long as twelve months. At the rate of flow which I advocate in the paper to which you refer the putrefactive changes are not so active as obviously to result in the production of bubbles of gas. The expression "putrefactive change" must cover, I am satisfied, a very great variety of changes indeed, only some of the later of which result in the production of the offensive matters which have drawn one's attention particularly to this tank question. I think, to begin with, the amount of simple soluble matter in excrement and sewage solids has been under-estimated very much. I had some experiments—they were not carried out so completely as I wished—but I had some experiments showing that quite considerable quantities are soluble in water under circumstances which did not allow any putrefactive change whatever. The extraction of such matters by chloroform water for instance shows that a very large amount is just soluble without any further putrefactive action at all. Then beyond that the changes included in the expression "putrefactive changes" must be of a widely varying character—must constitute a series of changes one after another. But I conceive that it is quite possible to carry out the earlier changes in a long series, and to avoid the later changes which are accompanied by the production of gases and offensive matters.

27019. Notwithstanding the increase in the flow which you suggest as a proper course to take, there must be some putrefactive change in the deposit?—Unquestionably it is going on.

27020. The interest of what you have brought before us seems to lie in this, that you think it is a mistake to leave the sewage in a tank for what has been the usual septic period of twenty-four hours?—Yes.

27021. And that it is better to pass the sewage through the tank more rapidly, but you point out that notwithstanding that more rapid passage there is in your opinion as great a digestion of suspended matter as there would be if you left it for the longer period which is usual in septic tanks?—I do not think I quite said that.

27022. I thought you had expressed a rather strong opinion to that effect?—May I just say that I think the destruction of sewage solids is probably progressive. If the sewage solids are left for twenty-four hours more are destroyed than in twelve hours. But I do not think the difference is very appreciable, and I think that that difference is counterbalanced by the formation of new solids.

27023. Secondary products. You suggest to us that by leaving the sewage for a shorter period in the tank you avoid the formation of those secondary products?—Precisely.

27024. And that although there may be some additional digestion in the longer period of tankage there is the disadvantage of getting these secondary products formed?—Exactly.

27025. What are the secondary products?—The secondary products are of two or three kinds. There are solid actual precipitations formed as a result of leaving the sewage longer than is desirable in the tank. There are soluble very offensive matters which give an offensive odour to the ordinary septic tank effluent. There is a great deal of gas formed, which I do not think is of very much importance, because gas which is evolved from these tanks is practically inoffensive, at any rate in an open tank. The objectionable secondary matters formed are the new solids, comprising, as I think I show, a considerable amount of ferrous sulphide which in consequence of its great appetite for oxygen is a most objectionable thing in an oxidising filter; and secondly I object to the offensive smells which result probably from the formatior of organic sulphides as a result of the overdetention of the sewage in the tank.

27026. If by your more rapid flow you avoid this formation of secondary products, what becomes of the matters which give rise to these secondary products when you pass them forward in the filtrate in solution or in colloidal solution on to the filter? Do they then in the filter settle out and come into suspension?—I think not necessarily. It is a very difficult subject you are putting to me.

27027. I want your opinion upon this. If by your more rapid flow you avoid this deposit in the tank, what becomes of the matters which give rise to the deposit; do they give rise to suspended matter in the discharge through the filter, which suspended matter is possibly acted upon by bacterial life, but the greater part of which comes out with the filtrate?—I think not—not at all. Take the instance of the ferrous sulphide. Assuming there are sulphates in the sewage under ordinary conditions the sulphate is reduced to sulphide, the iron in solution in

the sewage deposits in the later part of the tank; in the channels of the filter on the medium of the filter is a black solid uniform substance. If you hurry the sewage through the sulphates remain sulphates, and the solution passes through and no harm is done. Do you not find that in passing through the percolating filter there is a considerable discharge of matters from solution to suspension? I think you yourself said in an answer to Sir William Ramsay that in some cases you got as much or more suspended matter, though in a different form, than went in?—I do not think I found more, but I found nearly as much.

27028. Do you not think it likely that there is a considerable amount of matter discharged from solution into suspension?—I am not in a position to contradict that, but there is evidence by other investigators tending to show that this colloidal matter, if it exists, does assume visible shape on points of contact, but I do not think that my experiments show that necessarily. I think I can sufficiently explain the presence of the suspended solids in the final effluent by assuming that they are derived from the shredding away of the growth upon the particles of the medium. It is quite true it may be the case that the growth is in the first instance a mere deposit of solids resulting from colloidal matter in the tank effluent settling on the medium and becoming afterwards permeated with these organisms which the microscope shows you are there and are probably eating up and destroying this matter. That is a very nice point, and although as regards the practical treatment of sewage it does not very much matter it is a point we would like to decide.

27029. Coming to an essentially practical matter, do you foresee that there would be much advantage in substituting your more rapid flow for the slower septic flow seeing that the amount of suspended matter in the tank effluent will be about the same, and that the amount of suspended matter in the filtrate will be about the same; do you see that there is any great advantage in substituting the more rapid flow for the smaller flow, apart from the question of nuisance?—No, not apart from the question of nuisance.

27030. The avoidance of nuisance is the only advantage that you suggest would arise from having a more rapid flow into the tank?

27031. (*Sir Michael Foster.*) I thought your position was that the filter acted better on the tank effluent in the absence of the dark and later decompositions?—I was about to get that in reply. The offensive bodies are in themselves inimical to satisfactory filtration.

27032. (*Sir William Ramsay.*) You are doing a lot of work which has afterwards to be undone. Is not that the whole thing?—Exactly.

27033. (*Sir Michael Foster.*) Is it not rather that you are producing in your septic tank in these later stages things—to speak in a general way—which interfere with the proper action of the filter?—Yes. Those are the two points I raise in my paper—the offence and the difficulties introduced.

27034. (*Colonel Harding.*) The special advantage in your opinion is the advantage to subsequent filtration?—Yes.

27035. (*Sir William Ramsay.*) And also the matter of tank capacity. If you give it only half as long you require only half the capacity.

27036. (*Colonel Harding.*) What I really wanted to know was what you thought became of the matters which give rise to the secondary products in the septic tank?—I think they largely remain in solution and are unobserved.

27037. In fact, do you not think that there is in the filtrate, either from the septic tank or from your quicker flow tank, a considerable amount of suspended matter?—In the effluent?

27038. In the filtrate?—There is, in all cases. I do not know a single coarse filter of the type I approve of that is not giving such a filtrate.

27039. Then it is necessary in these cases to have a final sedimentation of these matters?—We are experimenting a good deal upon that. I have not been very successful with a settling tank. One was constructed at Horfield; we got rid of the blacks to a very great extent, but they did not settle as rapidly as we had anticipated. At several places—at Salisbury, as I think you are aware—they have been separating the deposit from the final filtrate on fine shallow beds with considerable success, except that it involved a certain amount of labour.

27040. Do you think the amount of suspended matter in such a filtrate would be too great to be allowed to go into the stream?—I think it would depend upon the special case in point. I should not suggest anything of the kind with regard to Bristol sewage if the Corporation chose to deal with it in this way.

27041. About what amount of suspended matter have you in the filtrate per 100,000?—More.

27042. Six?—Well, five.

27043. Do you suggest that that might safely be allowed to go to the stream?—In certain streams.

27044. In the condition of Bristol?—Unquestionably.

27045. Because you have there a large stream and tidal?—And not likely to be used for drinking purposes, and Bristol not being so situated as to cause trouble to places below.

27046. In regard to quite small installations, for either small village communities or mansions, or institutions, have you any experience of having put up little plants with tanks followed by filtration?—I should like to give you a description of one such plant.

27047. Where is it?—At an institution four miles out of Bristol—at Almondsbury.

27048. How many persons does it provide for?—It is a convalescent home and village club and a place of resort for a great number of cyclists and other visitors from Bristol, so that the population is an exceedingly variable one. The permanent staff is five nurses and commonly four or five patients, but the visitors on public holidays amount to hundreds.

27049. Have you carried out any installations such as I mentioned, for about twenty persons—a more regular population than in the example you were describing?—Yes, I have been concerned in a great number of schemes of about that size. I do not actually construct the works.

27050. Are you able to give us any experience in regard to such works carried out on your lines—quite small installations?—Great numbers of private houses and places of that sort are fitted with filters of this character, but this question of the tanks has only recently been developed.

27051. If you had a flow of 500 gallons a day your tanks would be exceedingly small—two feet square in these compartments?—Yes.

27052. Does that work practically?—No, I am afraid it does not. I am afraid that a tank of less than 500 gallons capacity cannot be satisfactorily worked upon this principle. And more than that; these very small installations are subject to this trouble, that the population fluctuates enormously. In a country house for instance, the occupants, with the exception perhaps of a caretaker or two, will go away for a month, and the whole thing will become exceedingly stagnant and putrid. There are several additional complications in regard to very small installations, and I am inclined to think that the proper course to adopt is that which was adopted in the case of the institution I commenced to describe just now. Briefly, it consisted of enclosing entirely the whole thing, establishing a current of air through the whole system from the outlet of the filter to the ventilation pipe on the sewer. It can be done quite easily without any prejudice to the action of the system as a whole, and the effect is the entire abolition of smell so far as the people are concerned.

27053. May I take it that your experience does not enable you to recommend to us any system of sewage treatment for either very small communities or small institutions and mansions where there are no sewers?—I cannot accept that, because I have frequently recommended systems, and many of them are working very well.

27054. Can you recommend to us one that would be suitable?—Unquestionably. I would have brought with pleasure a tracing of the plans of a system for a dozen people.

Mr. F. Wallis Stoddart, F.I.C., F.C.S.

8 Feb. 1906.

27055. You suggested that it was not practicable to use a tank system for less than 900 or 1,000 gallons, did you not? Or did I misunderstand you?—I am sorry if I conveyed that impression. I think I said that this suggestion of making a tank equivalent to half a day's flow cannot be carried out in its entirety on a small scale.

27056. For between 500 and 1,000 gallons a day can you on your plan suggest a plant to deal satisfactorily with so small a flow?—Oh, yes, for a flow of from 500 to 1,000 gallons a day undoubtedly.

27057. For 500 gallons?—Five hundred to 1,000, yes.

27058. You can?—Yes.

27059. What sort of plant would you use?—Simply a tank and a filter.

27060. Have you instances where such plants are at work and have been for some time?—Yes.

27061. Would you refer the Commission to them?—Certainly.

27062. If you would give Mr. Willis the addresses at which such plants can be seen, I think it would be of interest to the Commission?—I will do so with pleasure.

27063. (*Sir Michael Foster.*) Is it an open tank in these cases?—They vary. In the case of the institution I was describing just now the tank is, in a sense, open; it is not a covered tank in the usual sense, but the whole installation, tank and filter, is enclosed in a brick chamber. Another one not very far from the same spot has the tank constructed of the size I am suggesting, of only 450 gallons capacity, but it is roofed in exactly as a septic tank ordinarily is, and the filter is exposed at some distance.

27064. In none of these cases are you prepared to apply the system you have spoken of in your memorandum; you allow a longer stay in the septic tank?—Not because I desire the longer stay, but because the conditions, the variation of flow, and so on, compel one to compromise to a certain extent.

27065. (*Colonel Harding.*) In such cases you have to deal with an average, and you cannot help at times bringing about putrefactive conditions?—Exactly.

27066. And to avoid the evils resulting from that you suggest that the tank part of the plant should be covered up?—The whole plant.

27067. Including the filters?—Including the filters. The trouble arises from the exposure of the tank liquor as it is applied to the filter; that is where the real trouble arises. The smell very seldom arises from the open tank, in my experience, but the little disturbance resulting from the application of the tank effluent to the top of the filter—whatever means is adopted—seems to be sufficient to liberate the smell.

27068. On so small a scale would you recommend a tank capacity of about half the daily flow?—At the present moment I think the capacity cannot well be less than about 500 gallons; I think there are difficulties with a smaller capacity.

27069. That is what you advise with a small installation?—Yes.

27070. And would you advise the same division into sections that you show in your little pamphlet?—Not so many sections, of course, in so small a tank. They are generally constructed with one median submerged wall and two scum boards.

27071. We should be interested if you would give our Secretary the addresses at which such small plants, working satisfactorily, on your lines could be seen?—Very good. Might I just show the Commission a simple arrangement for sampling the sludge? (*Model produced.*) This is made in suitable lengths for the depth of the tank. A rod is provided with little pointed cups at intervals, and on being placed vertically in the tank the cups fill up to the top of the sludge, giving the exact measure of the condition of the sludge at different depths. It is far more reliable than the glass tube.

27072. (*Sir William Ramsay.*) One question as regards a difficulty experienced in the flow through the tank. For example, do short cuts occur? Does your liquor take short cuts, going through particular channels without making use of the whole tank?—That is undoubtedly the case, and it was with the idea of meeting that that these scum boards and submerged walls were introduced. You can readily see that the liquor is actually taking a short cut by watching the top of the submerged wall; you see the particles passing much more rapidly immediately over the wall.

27073. Is there any special shape of the tank to prevent these short cuts?—I have generally made them three or four times long as broad.

27074. And put in these boards?—Certainly.

EIGHTY-SIXTH DAY.

Tuesday, 29th May, 1906.

PRESENT:

The Right Hon. The Earl of Iddesleigh (*Chairman*), presiding.

Major-General Constantine Phipps Carey, C.B., R.F.
Sir Michael Foster, K.C.B., F.R.S.
Colonel T. W. Harding, J.P., D.L.
Sir William Ramsay, K.C.B., F.R.S.
Mr. T. J. Stafford, F.R.C.S.I.

Mr. F. J. Willis (*Secretary*).

ALSO PRESENT:

Dr. A. C. Houston.
Dr. George McGowan.
Mr. G. B. Kershaw.
Mr. C. C. Frye.
Mr. R. D. Littlefield.

Mr. George Reid, M.D., D.P.H., County Medical Officer of Health, Staffordshire, recalled; and further Examined.

Mr. George Reid, M.D., D.P.H.

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27075. (*Chairman.*) I think, Dr. Reid, all that I have to ask is, you put in this pamphlet and it will go down upon our minutes of evidence?—Certainly.

In my previous evidence before the Commission, I gave particulars of the working of a sewage disposal plant at Hanley, which had been constructed in order to determine whether single filtration of septic tank effluent through 4 ft. 9 in. filters would produce a good effluent in the case of the sewage in question. The filter plant, it will be remembered, consists of two beds, circular and rectangular, each having an area of quarter of an acre, and the filtering medium is broken saggers, graded to different sizes in four sections for comparative purposes, the distribution of the sewage on the filters being effected by highly efficient power driven apparatus, working at a delivery rate of 200 gallons per superficial yard per twenty-four hours.

It was proved by numerous analyses, extending over a

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period of eighteen months, that the best results were obtained from the fine grain sections of the filters ($\frac{1}{8}$ in. particles), and these effluents were of a very high standard of purity. As the Commission, in view of the entire absence of suspended solids in the filter effluents, desired to have fuller information regarding what became of the solids—both organic and mineral—during the different stages of the treatment, I have since conducted further tests with special reference to that point. I also tapped the $\frac{1}{8}$ in. grade section of the rectangular filter at different depths, introducing four rectangular shallow trays with perforated covers, from which pipes were carried through the filter wall; I was thus able to collect effluents from 1 ft., 2 ft., 3 ft., and 4.5 ft. depths.

In order that the results from the lower depths might not be affected by the presence of the trays above, the trays were placed obliquely, from above downwards, so that no tray had another in a vertical line above it.

In analysing the sewage and effluents, in addition to the estimation of the mineral and organic suspended solids, the process was carried further than is usual; for example, both the nitrous and nitric nitrogen were estimated at the time of collection, and again when the fuller analyses were made—in every case the day after collection.

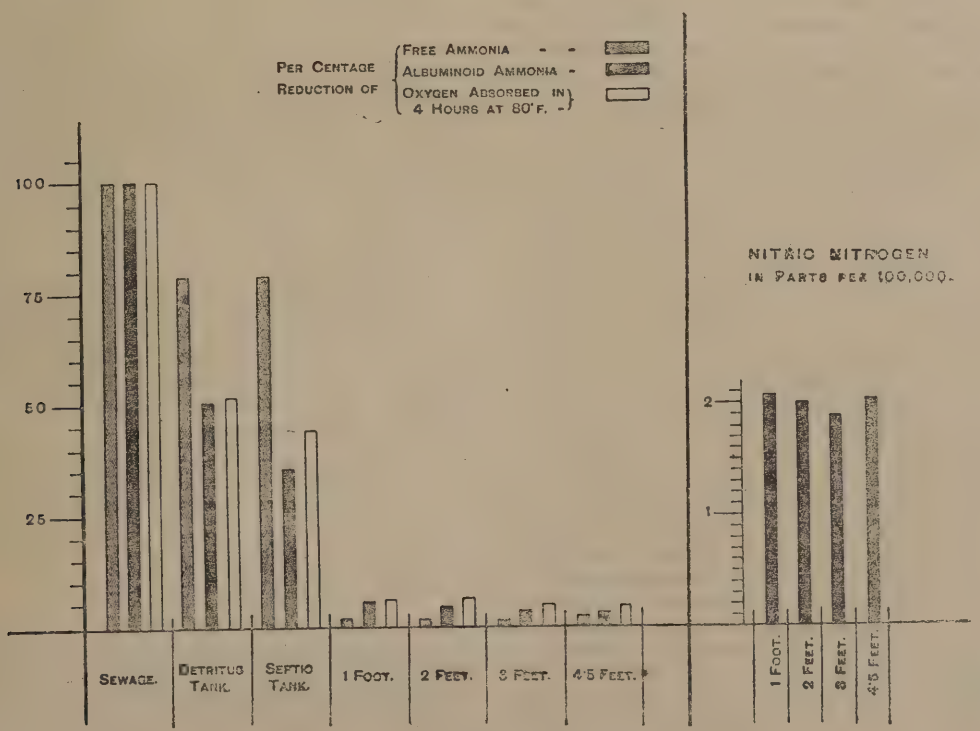
Samples of air were also collected from the filter at different depths for the purpose of estimating the amount of carbonic acid present; also the amount of solid organic matter in the interstices of the filter at different depths was ascertained.

The period covered by the analyses extended from July to December 1905, inclusive, the filter at the end of that time having been in continuous use for a period of three years, dealing with the septic effluent at the rate of 200 gallons per superficial yard.

In the following table the mean figures of analyses are given, and the diagram attached shows, graphically, the percentage reduction in the free ammonia, albuminoid ammonia, and oxygen absorbed figures at different stages in the treatment, as well as the actual nitric nitrogen figure expressed in parts per 100,000:—

Parts per 100,000.

Sample.	No. of Records.	Total Solids.	Solids in Suspension.	Solids in Suspension (Organic).	Solids in Suspension (Mineral).	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 4 hours at 80° F.	Oxygen absorbed in 3 minutes before incubation.	Oxygen absorbed in 3 minutes after incubation (3 days).	Nitric Nitrogen on day of collection.	Nitric Nitrogen day after collection.	Nitrous Nitrogen on day of collection.	Nitrous Nitrogen day after collection.	Column necessary to obscure test lines (inches).
ewage - -	18	170·9	63·5	28·5	34·9	11·0	2·154	0·972	5·019	1·862	2·176	0·02	0·10	0·029	0·029	0·5
Detritus Tank	13	118·1	17·0	6·8	10·1	10·0	1·643	0·486	2·726	0·975	1·095	0·02	0·09	0·014	0·022	1·6
eptic Tank -	16	107·8	7·6	3·8	3·8	9·9	1·716	0·340	2·184	0·836	1·571	Nil.	0·09	Nil.	Nil.	1·5
ilter, 1 ft. -	16	101·5	0·25	0·16	0·08	9·4	0·036	0·052	0·328	0 093	0·067	1·64	2·07	0·003	0·003	Over 24
„ 2 „ -	16	101·1	0·09	0·05	0·03	9·5	0·020	0·037	0·286	0·077	0·060	1·82	1·99	0·011	0·007	„
„ 3 „ -	16	101·8	0·14	0·06	0·08	9·4	0·009	0·031	0·244	0·060	0·052	1·75	1·85	0·005	0·008	„
„ 4·5 „ -	16	103·5	—	—	—	9·5	0·043	0·027	0·259	0·070	0·039	1·70	1·99	0·005	0·002	„



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Comments on Figures of Analyses.

1. With regard to the suspended solids, it will be noticed that a reduction of 73 per cent. is effected in the detritus tanks, and that a further reduction of 15 per cent. takes place in the septic tank, making a total reduction of 88 per cent., and resulting in an effluent being passed on to the filter containing 7.6 parts per 100,000, exactly one-half of which is mineral matter. This suspended matter, it will be seen, is practically all retained in the top layer of the filter where the organic portion is liquefied, in all probability by aerobic organisms. The mineral matter, however, must remain in the filter, and in time, no doubt, it will be found necessary to remove the filtering medium to a depth of a few inches for the purpose of washing it, but so far, after over three years' constant working, no such necessity has arisen. As a matter of fact, if the total mineral suspended solids passing on to the filter during the three years were deposited in a uniform layer over the whole surface the depth of the coating would be less than $1\frac{1}{4}$ inch.

2. The reduction of the free ammonia at a depth of one foot is remarkable, especially considering the fact that the change has been effected in about twelve minutes—the time occupied by the sewage in passing downward through the first foot of filter. In my experience it is not unusual to find the free ammonia figure reduced almost to an equal extent in effluents from fine grade filters, but, hitherto, I had no conception that the change was brought about by so shallow a depth of filter.

I may here mention that the rate of travel downwards of the sewage through the filter was found, as the result of several observations, to vary in accordance with the depth as follows:—

From surface to 1 ft.	- -	12 minutes.
,, 1 ft. to 2 ft.	- -	12 ,,
,, 2 ft. to 3 ft.	- -	6 ,,
,, 3 ft. to 4 ft. 6 in.	- -	5 ,,
Total	- -	35 minutes.

This is a slow rate of travel, compared with the rate in the case of large particle filters, which, in my experience in some cases, allow the sewage to pass through the entire depth of from four to five feet in about four minutes.

The free ammonia figure presents one other interesting feature. It will be noticed that the progressive reduction which takes place during the passage downwards through the first 3 feet is suddenly interrupted, a considerable increase in the amount being recorded at a depth of 4 feet 6 inches. Accidental error in analysis does not explain this, for the increase was invariably recorded, and, as a matter of fact, I verified the accuracy of the results by a second analysis in the case of the first few samples until it became quite obvious that no such explanation of the occurrence was feasible. I shall refer to this phenomenon later in dealing with the general arguments and conclusions.

3. As regards the albuminoid ammonia figure, it will be seen that a highly satisfactory reduction is effected by filtration through one foot only. In fact, this figure and the oxygen absorbed and nitric nitrogen figures considered together indicate a very high degree of purification which precludes the possibility of subsequent putrefactive change.

4. It will be seen that the reduction in the oxygen absorbed is, stage by stage, proportionate to the albuminoid ammonia reduction, and the rapidity of the change in this case also is equally marked.

5. With reference to the oxidised nitrogen, the figures are very startling, for, not only are they indicative of extremely healthy and active biological conditions, but considered in relation to the other figures, they also demonstrate conclusively, in the case of the sewage in question at any rate, that the work of purification is practically completed within a few inches of the surface of the filter. I must say that this result surprised me very much. Theoretically, one expected to find that the process was a more gradual and progressive one, nitrites being formed chiefly in the superficial layers of the filter and nitrates in the deeper layers, but this did not prove to be the case. At the same time, I do not suggest that the change is not gradational, but rather that the two sets of organisms are at work side by side, and in this case the absence of more than a trace of nitrous acid in the one-foot effluent, although the tests were applied at the moment of collection, may be accounted for by the preliminary stage of the oxidation process being an extremely evanescent one, owing to the highly efficient working conditions.

General Comments.

In advocating the use of fine filtering medium when discussing the subject from time to time with engineers and others interested in the question, the objections almost invariably urged against such fine medium are (1) the risk of clogging from suspended matter, and (2) the alleged defective æration. According to my experience, which is by no means confined to the work embraced in this paper, clogging is more likely to occur with large than with fine grade medium, owing to the fact that the suspended solids in the former case are not retained in the surface layers, where it would seem the active ærobic liquefying changes are effected, but are washed into the deeper layers where, in place of being liquefied, they accumulate and ultimately fill up the interstices. For this reason, if I were compelled to sacrifice my convictions and make use of large filtering medium, my inclination would be to adopt the suggestion which was the outcome of a long series of experiments at Leeds, and use such a large size as would allow of the suspended solids being washed through, and face the cost of providing means for their removal from the effluent afterwards. In other words, in my opinion, if clogging is to be avoided, the filtering medium must either be fine or very coarse; the solids must either be retained and liquefied on the surface or washed through and mechanically removed afterwards.

With reference to the second objection—the difficulty of æration—I fail to see why it should be advanced, in view of the incontrovertible fact that high nitrification is obtained by means of fine medium filters. Personally, I am satisfied that if it were desirable, which I think it is not, to use much finer medium than $\frac{1}{8}$ inch, there is no reason, from an æration point of view, why we should not do so. The only argument which weighs against the efficiency of a smaller grade medium than $\frac{1}{8}$ inch is, that with very fine material the suspended solids are apt to be retained on the actual surface, where rapid liquefaction cannot take place unless frequent raking and forking is resorted to. On the other hand, the suspended solids are in a sufficiently fine state of division to permit of penetration into $\frac{1}{8}$ inch medium, and being thus, I suggest, brought into intimate contact with highly active ærobic liquefying organisms, resolution is rapidly effected.

The three essential factors in the final changes are time air, and organisms, and, given a sufficiency of air, the greater the number of organisms present the larger the amount of work done, provided the organic matter, both in solution and suspension, is brought into intimate contact with the organisms. The factor which governs the bacterial population is the area available for growth, and this may be increased by two methods, either by enlarging the cubic capacity of the filter or by sub-dividing the filtering medium. In the case in point, as, indeed, in all cases in Staffordshire, the latter was the expedient adopted, and the sub-division was carried as far as it was thought possible to carry it without preventing the superficial penetration of the suspended solids into the interstices. In view of the results, it is needless to discuss whether the reduction in the size of particles resulted in an inadequate air supply.

The relative amount of carbonic acid in the air of the filter at different depths also shows the highly active oxidising changes which take place in the superficial layers. A series of samples of air aspirated from different depths by means of iron tubes driven vertically into the body of the filter while in continuous use yielded the following mean results:—

Carbonic Acid in parts per 1,000.			
1 ft.	2 ft.	3 ft.	4 ft.
19·5	21·5	20·0	20·0

An interesting fact bearing upon the aeration of the filter was incidentally made apparent by the method at first adopted of collecting the air. The distributor passing backwards and forwards over the filter was found to interfere considerably with the collection of the samples, and, to obviate this, the apparatus was periodically stopped for varying periods during the operation. Owing,

however, to extraordinary discrepancies in the results thus obtained, measures were taken to overcome this difficulty and enable the air to be collected without interrupting the regular flow of sewage on to the filter. The results, of which the figures just given are the means, were then found to be remarkably uniform, whereas in the case of the earlier samples the carbonic acid varied in amount according to the intervals which elapsed between the stopping of the distributor and the collection, short though these intervals were, from 2·8 to 26·1, showing how free was the current of air through the filter.

If, then, by using fine-grade particles, the depth of filter may be greatly reduced, the resulting economy would dictate such a course, but there is another important consideration, which, other things being equal, tells in favour of shallow filters, from the point of view of aeration. The air travels through a filter from above downwards, the direction of the current probably being mainly due to the percolation downwards of the sewage, and its more rapid flow along the effluent drains. The air, therefore, as it passes downwards, carries with it the products of the combustion which has taken place above, and thus has an asphyxiating effect upon the organisms below, and it is possible that even an aerobic fermentation may be revived in the bottom layers. The sudden increase in the free ammonia figure, noted in the case of the effluent from the lowest tray, may possibly be accounted for in this way, because the albuminoid ammonia figure does not represent the total organic nitrogen present, therefore there is an unrecorded margin of nitrogenous organic matter available for the revival of the ammonia change should this explanation of the phenomenon be the correct one.

Be this as it may, however, the phenomenon does not appear to be accounted for by fouling of the deeper strata. At the end of the observations the filter was opened and carefully examined throughout its depth, when it was found that the dark discolouration from deposit was confined to the surface, as was evident from the untarnished appearance of the light-coloured filtering medium below the top 14 to 18 inches. Also, the relative amount of organic solids in the interstices at different depths, ascertained by drying and igniting 10 grammes of the filter particles in each case, supports this contention, as the following figures show :—

Percentage Loss on Ignition of Filter Particles at different depths.

6 in.	1 ft.	2 ft.	3 ft.	4 ft.
3·25	0·99	0·65	0·53	0·53

Apart from all theory, however, the fact has been established beyond all doubt, that, in the case of the sewage in question at any rate, the lower two or three feet of filter medium is absolutely unnecessary, and, so far as the cost of construction of the filter is concerned, the expenditure might be reduced by about one-half. Again, from the point of view of cost, another important consideration comes in. It frequently happens that the absence of two or three feet of available fall is the determining factor between a gravitation and pumping scheme, and in this respect the reduced depth of filter might lead to further economy, not only in capital outlay, but in maintenance charges.

Now, the question may be asked whether the experience acquired at Hanley may be applied in other cases where the sewage may be of a stronger character ? I am not at present in a position to give a positive answer to that question, but if, as is probable, such should prove not to be the case, the observations I have recorded clearly point to the conclusion that the extra filtering capacity should be provided for by increasing the area rather than the depth of the beds. The three factors in the nitrifying process being a given time, a given volume of air, and a given bacterial population, all these would be supplemented by extending the area in accordance with the combustion which has to be effected, and thereby diminishing the delivery per square yard of filter.

I have lately had an opportunity of applying the information recently acquired at Hanley in the case of a town in Somersetshire, where the sewage is much stronger and contains brewery refuse.

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A scheme, which had been based upon experiments previously conducted by the Surveyor of the district, was submitted to me for approval. The experimental filters, which had a depth of 4 feet 6 inches, were composed of clinker, broken to sizes varying from ¾ inch to ½ inch, the distribution being by means of sprays.

The results obtained were fairly satisfactory as regards nitrification, but the organic matter remaining unconverted was considerable, and the effluent, so far as appearance went, was a poor one. The engineer, however, had recommended a scheme on similar lines, but with 5 feet 6 inch filters, believing that the extra depth would effect further and adequate purification.

In view of my Hanley experience, I recommended that the experiment should be continued, one-half the area of the filter being altered as follows :—The top 12 inches of clinker to be removed from one-half the area of the filter and replaced by ¼ inch to ⅜ inch granite chippings, and a collecting tray to be introduced at a depth of 3 feet from the surface of this altered section. We thus had an opportunity of comparing the results obtained by the altered section at depths of 3 feet and 4 feet 6 inches with those from the undisturbed section at a depth of 4 feet 6 inches, under identical working conditions.

So far, I have had an opportunity of analysing two sets of samples from the two sections of the filter, and the following are the means of the more significant results obtained :—

	Parts per 100,000.		
	Unaltered section of filter at 4 ft. 6 in. deep.	Altered section of filter at 4 ft. 6 in. deep.	Altered section of filter at 3 ft. deep.
Solids in Suspension	2·10	1·15	1·00
Free Ammonia	0·710	0·250	0·067
Albuminoid Ammonia	0·154	0·107	0·044
Oxygen absorbed in 4 hours at 80° F.	0·818	0·680	0·368
Nitric Nitrogen	1·04	1·16	2·58

It will be seen that the improvement effected by apparently so trivial an alteration is remarkable. The improved quality of the effluents from the altered section of the filter at a depth of three feet compared with those from the same section and the unaltered section at a depth of 4 ft. 6 in. is most striking.

If, then, my conclusions are generally applicable, their bearing, from the point of view of the present requirements of the Local Government Board, is of considerable importance. So far as the nitrifying beds are concerned, cubic capacity in relation to sewage flow appears to be the governing factor as regards the Board's requirements, and while a minimum depth of four feet is imposed, it is permissible to extend the depth even to nine feet, the surface area being reduced in proportion.

This rule, when we come to apply it, works out as follows :—The Board's standard, as regards working capacity per day, is 56 gallons per square yard per foot deep, so that, given a filter four feet in depth, the daily volume passed through it would be 224 gallons per superficial yard, as compared with 504 gallons, the permissible volume in the case of a filter nine feet deep.

Further, it does not concern the Board what sized material is used to form the beds ; lumps of from two to four inches in diameter being as readily approved as particles of ⅛ in.

Of course I do not suggest that the depth of fine-grain filters may be reduced to one foot, because we must allow for the effluent drains and the few inches of large material immediately on the top of them, but I do suggest the practicability of reducing the total depth to, say, 2 ft. 6 in.

(*Signed*) GEORGE REID.

County Council Offices,
Stafford,
22*nd May*, 1906,

Mr. George Reid, M.D., D.P.H.

29 May 1906.

27076. I think all I have to say is that we are very much obliged to you.

27077. (*Sir Michael Foster.*) You have not made any bacteriological observations together with your chemical?—No, I have not.

27078. You have not any additional cases besides your own experiments. There is that remarkable result which you obtained down in Somersetshire; have you any further trials?—Not at present, but I expect that we shall have in Birmingham very soon. They have recently constructed a fine grade-filter there.

27079. With the same depth?—Well, they are going to introduce trays in order to ascertain what purification is effected at different depths in the case of the Birmingham sewage.

27080. (*Sir William Ramsay.*) Dr. McGowan wants me to ask one or two questions on technical points. One relates to the arrangement of the trays and the lateral distribution; for example, are the trays set from one another?—About 18 inches laterally from one another.

27081. I presume that the expression "dealing with the sewage" should be "dealing with the septic tank liquor at the rate of 200 gallons per superficial yard"?—Quite so, yes.

27082. How was the rate of flow tested?—The filter was stopped working. This is the mean of a series of tests. The filter was stopped working entirely. That is to say, the distributor was stopped travelling entirely and when the flow ceased from the pipes coming away from different depths it was then started, and when the flow recurred from these pipes it was noted.

27083. (*Sir Michael Foster.*) Then is the flow through an empty filter?—Well, it is the flow through the filter immediately after it has been treating sewage; it was not allowed to drain for any time.

27084. But there was not, I suppose, as much fluid in the space as there was when it was in working order?—There would not be; not in the interstices.

27085. No, quite so; that would tend to increase the rapidity, would it not?—Well, I do not know that it would.

27086. It is not the measure of the actual rate of working the filter?—No, perhaps not, the only way to get that would be to colour the septic effluent and note the time occupied in the passage of the coloured effluent downwards.

27087. You did not try that?—I did not try that, no; the method adopted is comparative with other tests that I have made with regard to large particle filters in which the sewage took about four minutes to go through 4 to 5 feet.

27088. (*Sir William Ramsay.*) I do not know whether Dr. Houston has any remarks to make on the statement that "clogging is more likely to occur with large than with fine grade medium, owing to the fact that the suspended solids in the former case are not retained in the surface layers, where it would seem the active ærobic liquefying changes are affected, but are washed into the deeper layers where, in place of being liquefied, they accumulate and ultimately fill up the interstices." The idea is that the suspended solids are being brought into intimate contact with ærobic liquefying organisms.

27089. (*Dr. Houston.*) I should think that is correct, that on the surface liquefaction would be all right.

27090. (*Sir William Ramsay.*) It is suggested that the "carbonic acid varied in amount according to the intervals which elapsed between the stopping of the distributor and the collection, short though these intervals were from 2·8 to 26·1"; how was it estimated?—Do you mean how was the carbonic acid estimated?

27091. Yes?—It was aspirated into gallon jars, and baryta water used as indicator.

27092. Is it permissible to name the town in Somersetshire that you allude to?—Frome; I did not like to mention it in the evidence.

27093. Perhaps you do not want it mentioned?—I do not think it matters now. That was a very striking result we got at Frome from simply one foot of fine material on the top of the original filter. That is an example of a filter where the particles in my opinion being large were not large enough. That is a case in which the solids got entangled in the body of the filter and remained there.

27094. In view of your recommendation Dr. McGowan would like to know what is the state of the lowest 1½ feet of filtering material when this change was made; was it full of organic solids?—I do not quite gather what you mean.

27095. Well, you make a suggestion that you should alter the area of the filter and compare the results obtained by the altered section at depths of 3 feet and 4 feet 6 inches with those from the undisturbed section at a depth of 4 feet 6 inches under identical working conditions. What was the appearance of the filtering material at the lowest point; was it full of organic solids?—I did not see it personally, but I had a letter from the surveyor, in which he said it was full of organic matter from top to bottom; and so much so, that I recommended him to wash it out with town water at considerable force; he in this way got a good deal of solids away from it.

27096. (*Major-General Carey.*) When coarse-grained filters are used, are you of opinion that the solids which are washed through must be removed afterwards?—It is a very foul-looking effluent if they are not removed afterwards. I think they ought to be removed, otherwise it necessitates turning a large amount of solids into the streams, and if the streams are small and the sewage of large volume, it must affect the appearance of the stream unless the solids are removed.

27097. Is that borne out by the experiments at Leeds?—At Leeds, I understand they do take them out by fine filtration afterwards; at Birmingham they take them out by subsidence in tanks as no doubt the Commission know.

27098. (*Colonel Harding.*) There are a few questions I would like to ask Dr. Reid. I have not had the advantage until just now of seeing his report, but I notice that he comes to a very definite conclusion in regard to the superior efficiency of the first foot depths of the filter?—I do not say it is superior; I say the work is down at that depth and nothing much is effected afterwards.

27099. In other words you find the first foot of your filters apparently does the great bulk of the work?—Yes.

27100. And it is work which you consider to be sufficient on analysis?—Oh, quite sufficient; it is a very high standard of effluent.

27101. And you seem to have come to the conclusion that it is a mistake to increase filters in depth?—I think so; if an increase is necessary by reason of the increased strength of the sewage you will get more benefit by increasing the area than by increasing the depth.

27102. Have you tried experiments with a given quantity of material, say a cubic yard, to find out whether you got better results from that material at a depth of 3 feet or extending its areas, so that the depth would be only 1 foot?—Putting on the same quantity of sewage?

27103-4. Yes?—No, I have not.

27105. That would be necessary, would it not, in order to ascertain exactly whether there was any value in depth. Suppose, for instance, you had a cubic yard of material spread out one foot deep?—Yes.

27106. And you had the same cubic yard of material 3 feet deep?—Yes.

27107. And you passed the same sewage at the same speed though it?—Yes.

27108. That would be a very interesting experiment?—And I should say from the result of this work that you would get a better result from the same discharge on to the 3 yards area filter 1 foot deep than you would on to the 1 yard filter 3 feet deep.

27109. That is merely a surmise, is it not?—Yes, but I think it is borne out by this experiment plus the practical working at Frome.

27110. One experiment that we have tried does not quite bear out that?—Oh!

27111. But it would be very interesting if it were possible for you to try that experiment?—Yes, you see my time is so very much occupied in the practical work of

sewage disposal, and it is so difficult to get time for special experiments. I have done a great deal as it is, and it is so very very difficult to get time to do much more ; it might very well be tried, of course.

27112. (*Sir Michael Foster.*) Colonel Harding's suggestion is to obtain a direct verification of the conclusions you have drawn from your observations ?—Yes, of course it could be done on a small scale. To construct works of the size that these experiments would be rather expensive, but it could be done on a small scale.

27113. (*Colonel Harding.*) Yes ?—Then the difficulty of fine distribution would come in. This, of course, is perfect distribution, as you know ; you have seen the distributor at work.

27114. You would agree that unless you have very perfect distribution there would be great danger in having shallow filters ?—I do not think there would be any more danger than with medium depth filters.

27115. But surely if you have unsatisfactory distribution you are safer with a deep filter than with a shallow filter ?—You are safer with a deep filter if it is composed of large particles because then you consider the area for bacterial growth which you lose enormously. The size of particles in this experiment, as compared with 2 inch particles, gives you a population of nearly fifteen times as many bacteria.

27116. On account of the greater surface ?—Yes, the surface is not sixteen times greater, as one would suppose, because when it is broken into fine material it occupies more space than the large material. I measured it very carefully and I found the actual increase in area within the same space to be as 14·7 to 1.

27117. Now to enable us to gauge the interesting results that you bring before us, I would like to ask how exactly those trays were constructed, and how they were placed in the filter. You placed the trays at depths of 1, 2, 3 and 4 feet ; I suppose you removed the material to put in the trays ?—I put the material back again as far as possible in the same position.

27118. They had covers ; what were the depths of the trays ?—They had covers and the depths of the trays were about 4 or 5 inches.

27119. And the covers were perforated with what sort of holes ; how many ?—It was perforated wire simply, fine wire mesh.

27120. So that they were in effect boxes 6 inches deep with a wire mesh cover ?—Yes, but not quite 6 inches deep ; they were shallower than that ; they were about 4 inches deep ; they were about 12 inches wide and 3 feet long.

27121. And what was the size of the pipe leading from them ?—Inch pipe.

27122. And there would be a continuous flow from that pipe ?—Yes.

27123. So that you had not to deal with stagnant conditions but continuous flow ?—Continuous flow, the same as if you were taking it from the normal effluent pipes of the filter.

27124. It has occurred to me that the same experiment could be tried with these trays as placed in that bed if it were possible to somewhat reduce the flow over the square yard ?—That is the difficulty ; that is the great difficulty ; I could not possibly do it in that filter.

27125. Would it not be possible to introduce a sort of tray on the surface that would lead away part of the flow so as to reduce the flow to one third on to that square yard ?—I do not see how trays could do it without covering a considerable area of the surface,.

27126. If you covered a square yard ?—With a tray ?

27127. The tray on the surface would have the object simply of reducing the flow on that square yard ?—I do dot see how you could get it on the tray and distribute it over the whole yard.

27128. I confess there is a difficulty : that would have to be thought out ?—It could very well be done by constructing special filters, and say with a revolving distributor working two filters at the same rate of flow, one 3 feet deep and one 1 foot deep.

27129. They must not be at the same rate of flow ?—The same rate of flow upon the 3 yards of the area.

27130. The same rate of flow upon the 3 yards as upon the 1 yard in the other case ?—Yes.

27131. That would be a necessary experiment in order to check these results ?—That, I think, would not be necessary in order to demonstrate that my conclusions from these results are correct. These results are perfectly correct as they stand ; in the case of the Hanley filter the results as shown here are as obtained at different depths.

27132. Well, you obtain from the second foot a comparatively reduced result from what you obtain from the first foot ?—Yes.

27133. It remains to be seen whether that is due to the first foot being placed at the top. Of course the liquid you treat in the second foot is in quite a different condition to the liquid which is placed on the first foot ?—Yes, it contains no solids ; practically all the solids are on the top.

27134. The second foot does less because there is less to do ?—Oh, very likely.

27135. So that it is impossible to draw safe conclusions from those interesting data, unless one tried the experiment that I suggested ?—Oh yes, I quite agree with that ; but I have very little doubt that that would be the result.

27136. (*Sir Michael Foster.*) You draw from your results the conclusions that the purification of the 1 foot is so good that the lower purification may be neglected ?—Certainly, in this case it is so good. It is really a very high class effluent. It contains over two parts of nitric nitrogen, and only 0·05 parts of albuminoid ammonia per 100,000.

27137. (*Colonel Harding.*) Of course these are in the special circumstances of Hanley ?—Of Hanley.

27138. Which are somewhat special ?—Then if you apply the same thing to Frome with a much stronger sewage you find practically the same result.

27139. (*Sir Michael Foster.*) You have no results from Birmingham yet ?—No, not yet.

27140. (*Colonel Harding.*) You seem rather to disapprove of the present conditions laid down by the Local Government Board, by which they make the cubic capacity the standard ?—Yes.

27141. What is just your objection to cubic capacity being made the standard ? The cubic capacity I mean is rather convenient as an administrative unit ?—In order to get these results from the superficial layers of the filter, I do not think it is desirable to increase the flow beyond 200 gallons per yard, whereas if you allow cubic contents only to influence you, you increase the flow on the top yard of your 9 foot filter to 504 gallons per yard, and if I put Hanley sewage on at the rate of 504 gallons per yard we should not get a result approaching the result we get, and in my opinion depth would not give it, so that what I will say is, by all means increase the area if the sewage requires it, but do not come to the conclusion that you get the same result from increased depth.

27142. (*Sir William Ramsay.*) I suppose you would increase the area for a stronger sewage, would you not ?—Well, that is my idea at present. I shall be able to say more about that when we see the results from Birmingham.

27143. Which is a stronger sewage ?—Which is a stronger sewage.

27144. (*Colonel Harding.*) But assuming for the moment it was found that you got similar results from passing through a given flow with a three foot depth, and one third of that flow through a one foot depth, it would not interfere, would it, with the unit of cubic yard capacity ?—Oh, but I go a great deal further than that. I say it does not follow that to get a result you must necessarily increase your area three times. Probably a very small increase of area would suffice; reducing the flow from 200 to 150 gallons, we will say an increase of area of one quarter would probably be sufficient to give you a high class effluent with stronger sewage.

27145. All you wish to say is, that it is desirable to distribute the material over as large an area as practicable with a reduced depth, rather than gather it into a small area with a great depth ?—Yes, I say you will get a far better result from the same capacity of filter, we will

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say at 2 feet 6 inches to 3 feet depth, than you will get from a filter the same cubic capacity 6 feet deep.

27146. That is providing always you are using fine material and you are treating sewage of the same character as at Hanley ?—Sewage of the same character as at Hanley and Frome ; that is as far as I have gone at present, but I should like to say we have not any large grain filters in Staffordshire, and we have very high class effluents. It is not a new experience ; it is only new as showing the depth at which purification is effected. We have known all along that we get higher results from fine grain filters as compared with large grain filters.

27147. But the fact must not be left out of consideration that with fine grain filters you must have perfect distribution ?—You ought to have perfect distribution with any form of filter.

27148. But it is specially important in the case of fine grain filters ?—I do not know that it is specially important. I think it is less important with fine grain filters to have uniform distribution than with large grain filters, because the particles themselves assist in the distribution under the surface.

27149. I was not speaking of differences of size of material, but difference of depth of material. If you have a shallow depth of material, especially if it be coarse, where you have irregular distribution you have very unsatisfactory results ?—Oh yes, certainly.

27150. So that regularity of distribution is essential no doubt in all cases, but it is specially essential in the case of shallow filters ?—Oh, I should say so, yes. But not so essential in the case of fine grain as compared with large grain.

27151. (*Sir William Ramsay.*) Do you think that later on you will be able to make any sort of rule whereby the area could be proportionate to the strength of the sewage ?—Well, of course, one would have to have a very large experience before one could establish a rule. It might very easily be settled for each individual sewage, of course.

27152. By experiment ?—By experiment, yes.

27153. But such a rule might later on be stated ?—Oh, certainly, I should say so.

27154. (*Colonel Harding.*) I notice you point out, and probably you are quite right in doing so, that it is well that the material should be either very fine or very coarse ?—Yes.

27155. But in the case of fine material is there not a danger, where much suspended matter comes to the filter, that you get a layer of more or less impervious matter very soon on the surface ?—I do not think you would get it with material of the size that we use at Hanley. You would get it with sand ; of course they get it in America with sand.

27156. In your case at Hanley you have very little suspended matter coming to the filters, but such as does come is retained, I suppose, very near the surface ?—Just within a few inches ; there is none on the surface at all ; it is all inside the filter.

27157. It is within the first few inches ?—It is within the first twelve or fourteen inches after three and a half years' working.

27158. (*Sir William Ramsay.*) The capacity of the filter is not materially reduced, I suppose ?—There is no water-logging whatever, and the sewage gets away quite as freely now as it did when the filter was started.

27159. (*Colonel Harding.*) How long have these filters been working ?—Three and a half years.

27160. You do not find any more difficulty now than you did at starting ?—No ; we could pass a great deal more through only we would not get such a high-class result.

27161. No pooling ?—Probably it would begin to clog if we did pass much more through habitually.

27162. Probably you would ascribe some of the good results to the fact that the distribution is intermittent ?—I do not think it would matter ; if it could be made uniform and continuous I do not think it would affect the result.

27163. As a fact you have an intermittance of about ten minutes ?—Seven minutes.

27164. Seven minutes ?—Five to seven minutes.

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Appeal to central board would meet difficulty, *ib.*, 20122–3.
Carting away sludge financially impossible, *ib.*, 20124–9.
No complaints as to inconvenience of dam sludging, *ib.*, 20131.
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Sludging should be done at holiday times with notice to lower millowners, *ib.*, 20162–7.
Some control over sludging necessary, *ib.*, 20168–83.
Dams sludged once in three years, *ib.*, 20170–3.
Satisfied with control of Rivers Board, subject to appeal, *ib.*, 20180.
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Works would have to be closed ten to twenty-one days for wheeling out sludge, *ib.*, 20193–9.
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Would not reach well at bottom of dam, *ib.*, 20203.
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Black matter from mill reservoirs most objectionable, *Valentine*, 22496–9.

No appreciable nuisance from percolating filters; crowds of flies extremely objectionable, *Fowler*, 22840.

No serious nuisance from septic tank, except the gas evolved from sludge, *ib.*, 22785.

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First flush of effluent generally putrescible, *ib.*, 22471.

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Tanks cleared every six weeks to three months, *Valentine*, 22505–11.

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Water supply about 23 gallons per head, *ib.*, 22570.

Quality of water, *ib.*, 22571.

Drainage area about 3,700 acres, *ib.*, 22572.

Number of pails, etc., and water closets, *ib.*, 22573.

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Average dry weather flow about 4,500,000 gallons in winter and 2,700,000 in summer, *ib.*, 22574.
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Trade effluents are not poisonous, *ib.*, 23193.
Quantity and schedule of effluents at Sheffield, *Wike*, 23499.
Regulations under consideration, *ib.*, 23500; *Haworth*, 23654.
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Effect of each kind of trade waste, *Haworth*, 23596, 23646–55.
Sewage acid during discharge of iron pickle, *ib.*, 23603.
Equable flow desirable and necessary, *ib.*, 23655.
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Causes serious nuisance, *ib.*
No rules for reception of effluents except as to temperatures, *ib.*, 24669.
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Rules for reception of effluents, *ib.*, 24931, 25063–8.
Serious trouble caused by sudden discharges, *ib.*, 24932.
No disputes regarding trade effluents, *ib.*, 25045–6.
Greasy matter destroyed by sulphuric acid, *Scudder*, 25837–9.
Treatment is very costly, *ib.*, 25840.
Clay in "slip" increases sludge, *Willcox*, 26003, "Slip" appears to aid sedimentation, *ib.*, 26257–64.
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ULVA LATISSIMA:

Difficulties at Belfast, *Letts*, 24650.
Other localities where found, *ib.*, 24651–2, 24880–2.
Character of the nuisance, *ib.*, 24690–4.
Scheme of using the *ulva* for purification, *ib.*, 24757–80, 24850–60.
Use of sulphate of copper to check growth, *ib.*, 24793–8.
Carting away is very expensive, *ib.*, 24871–4.
Has ameliorated but not cured the nuisance, *ib.*, 24875.
Nuisance at Dublin due to sewage rather than *ulva*, *ib.*, 24883–6.

VALENTINE, A. H., M.SC. (Analysis of his Evidence.)

Chemist to the Oldham Corporation, 22382.
Oldham sewage treated by sedimentation and single contact, 22383.
Average dry weather flow; winter, 3,352,230 gallons; summer, 2,265,900, 22384.
Maximum dry weather rate of flow 6,700,000 gallons, 22385.
Minimum dry weather rate of flow 750,000 gallons, 22386.
Maximum wet weather flow at rate of 36,000,000 gallons, 22387.
Largest amount past last overflow between 24,000,000 and 25,000,000 gallons, 22388.
Annual rainfall about 5,300,000,000 gallons, 22389.
Volume of sewage in 1903, 2,062,406,000; in 1904, 1,682,954,000 gallons, 22390.
Infiltration varies with the weather, 22391.
Only a small volume of trade waste, 22392.
Black matter from mill reservoirs most objectionable, *ib.*, 22496–9.
Average amount of suspended matter, 22393.
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VALENTINE, A. H.—*cont.*

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Cost and advantages of separate and combined systems, 22408, 22506.
Rate of flow through settlement tanks, 22409.
Average analysis of tank liquor, *ib.*
Combined system of tanks advantageous, 22411, 22558.
Character of sludge varies with the season, 22413.
Heavy suspended matter should be removed, 22414.
Farmers take the sludge and pay cost of removal, 22415.
No chemical poisons in the sludge, 22416.
No nuisance from settlement tanks, 22417, 22512.
Chemical precipitation more effective than settlement, 22419, 22513–7.
Septic system preferred to chemical precipitation, 22419.
Value of different precipitants, 22420.
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Lime added to sludge, 22423.
No nuisance from chemical precipitation tanks, 22425.
Construction and working of septic tanks, 22426–45, 22546–62.
Over-septicising produces sulphuretted hydrogen, carbonic acid, etc., 22435.
Great difficulty in filtering such liquids, *ib.*
Conditions brought about by stagnation in tank, *ib.*
Sludge should be removed periodically, 22437–8.
First portion of storm sewage should go through tanks, 22440–1.
Septically treated sewage most efficiently dealt with on filters, 22442.
No nuisance from septic tanks, 22445.
Suspended solids should be removed before filtration, 22446–8.
Construction and working of contact beds, 22449–77, 22494.
Well settled storm tank effluent may be streamed through secondary bed, 22460.
Rate and causes of loss of capacity, 22462–5.
Average analysis of single contact effluent, 22466.
Suspended matter in primary effluent, 22469–70.
First flush of effluent generally putrescible, 22471.
Suspended solids greater in storm times, 22472.
Beds may be used as streaming filters, 22473.
Analysis of gases from bacteria beds, 22475.
No nuisance from contact beds, 22477.
Comparative cost and advantages of percolating filters and contact beds, 22479–81.
Storm filters should not be worked intermittently, 22482–3.
Suggestions for disposing of sludge, 22484.
Constituents of a good effluent, 22484*.
Aeration compared with permanganate test, 22486, 22524*–31.
One standard for all effluents not possible, 22487–8.
Automatic systems not considered reliable, 22489.
Value of the different chemical tests, 22491.
Quantitative determination of strength, 22492.
Filters get washed out during storm, 22506–7.
Tanks cleared every 6 weeks to 3 months, 22508–11.

WALTHAMSTOW:

Experiments in sludge burning, *Goodrich*, 25504 *et seq.*

WATER SUPPLY:

Should be beyond reach of pollution, *Fowler*, 22858 (*d*).

WATSON, GEORGE, M.INST.MECH.E., A.M.INST.C.E. (Analysis of his Evidence.)

Managing director, Horsfall Destructor Co., 25423.
Practicable to burn sludge in destructors, 25424.
Necessary to mix it with twice its weight of town refuse, 25425–8.
Air-dried sludge can be burned, 25429.
Cost of pressing 2s. per ton, 25430.
No nuisance from burning sludge and house refuse, 25431, 25465–7.

WATSON, GEORGE—*cont.*

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Cost of works about £12,000, 25440.
Cost of upkeep 10d. to 1s. 6d. per ton, 25441–54.
House refuse alone gives better result, 25447.
Lime would have to be slaked, 25448–9.
Pays better to sell sludge if a market for it, 25455–9.
Clinker soft and porous—lime in it, 25468–71.
Other means of disposal would cost less, 25475–9.
70 to 90 per cent. of moisture in pressed cake, 25480–5.
Would pay if burnt with colliery pit heap, 25486–7.
Fuel value of cake small except at Elland, 25488–9.

WATSON, J. D., M.INST.C.E., AND F. R. O'SHAUGHNESSY. (Analysis of their Evidence.)

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General scheme comprises sedimentation, septic tanks, percolating filters, and land, *ib.*, 25175–86.
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Quality of the water, 24918.
Gross and nett acreage of drainage area, 24919.
Proportion using pails or middens and water-closets, 24920.
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Maximum dry weather flow 35,560,000 gallons, 24922.
Minimum dry weather flow 10,560,000 gallons, 24923.
Maximum wet weather flow at the rate of 260,000,000 gallons, 24924.
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Best measure of "strength" of sewage, 24938, 25074–9.
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Sewage never acid on entering the tanks, 24941.
Suspended solids in storm times, 24942.
Sewers mostly laid in 1852–79; not much sinking, 24943.
Character of liquid in storm times, 24944.
Treatment of sewage in storm times, 24945, 25080–91, 25187–279.
Shape and size of storm overflows, 24946.
Standard form possible, present form unsatisfactory, 24947.
Not necessary to allow for configuration of ground in designing overflow, 24948.
Overflows should be adjustable, 24949.
Dilutions should depend on nature of stream, 24950.
Road water conveyed separately to water-courses, 24951.
First flush of storm should be purified, 24954.
Cost and advantages of separate and combined systems of sewers, 24955.
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WATSON, J. D., AND F. R. O'SHAUGHNESSY—*cont.*

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Settlement tanks used in parallel, 24959.
Baffling boards are of considerable use, 24960.
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Suspended matter very finely divided, 24971.
Not necessary to treat sludge before pumping it on to land, 24972.
Treatment, apart from sludge, never a nuisance, 24975.
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Reason to think it possible to "over-septicise," 24984.
Present methods of sludging, 24986–8, 25108–15.
No nuisance attends the operation, 24988, 25305.
Suspended solids in tank liquors, 24989–90, 25051–2, 25316–26.
No good purpose served by passing storm water through tanks, 24991–2, 25116–7.
May be admitted to a limited extent, 24993.
Impurities in sewage not materially different from those in tank liquor, 24996.
No appreciable difference in plain and filled tanks, 24997, 25118.
No nuisance from septic tanks, 24998, 25305.
Suspended solids should be removed before filtration, 24999.
Sedimentation in suitable tanks sufficient, 25000.
Dortmund tanks effectively remove suspended matter, 25001–2, 25352–3, 25402.
Cost and advantages of the various methods of settlement, 25003, 25053.
Construction and working of percolating filters, 25004–27, 25112–24, 25327–94.
Best materials for percolating filters, 25004, 25119–21, 25408–22.
Depth required to obtain a good effluent, 25005, 25054–5.
Tank treatment desirable before percolating filter, 25006.
Nature of suspended solids in effluent, 25018–21, 25125–32, 25359.
Experiments in removal of suspended solids, 25020.
Cost of percolating filters per acre, 25022, 25057.
Oxidation of ammoniacal and organic matter, 25023–4.
Purification less in cold weather, 25025.
Some trouble caused by vegetable growths, 25026.
No nuisance from percolating filters, 25027.
Comparative cost and advantages of percolating filters and contact beds, 25028–30, 25404–17.
Figures relied on for defining the strength, 25031.
Experience of storm-water filters, 25032–3.
Practical suggestions for disposing of sludge, 25034–5.
Constituents of a good effluent, 25036
Effluent from percolating filter should not differ from effluent from contact bed, 25037.
Test relied on in judging quality of effluent, 25038.
Aeration test most excellent but not sufficiently rapid, 25039, 25133–8.
One standard neither possible nor desirable, 25040.
Standard should depend on local conditions, 25041.
Effects of discharging known effluents into water of known volume, 25042, 25139–64.
Value attached to the different chemical tests, 25043.
Quantitive determination of strength, 25044.
No disputes regarding trade effluents, 25045–6.
Land effluent tends to fungoid growths in channel, 25139–54.

WATSON, J. D., AND F. R. O'SHAUGHNESSY—*cont.*

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Immediate formation of central board hoped for, 25256.
Sludge should be withdrawn from septic tank every three or four months, 25309–15.
Some treatment necessary after percolating filter, 25344–65.
Proposed new system of removing suspended matter, 25346.
Possibility of harm from over-filtration, 25359–69.
Septic treatment of sludges, 25375–83.

WEIRS:

Local authority should have power to remove derelict weirs, *Somerville*, 20252–3; *Reid*, 20677–82, 24440–1.

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Analysis of water of rivers and becks, *Wilson*, pp. 522–48.

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Not stronger than Act of 1876 with regard to dam sludging, *Wilson*, 23939–3.

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Analysis of water of the river, *Wilson*, p. 540–1.

WIKE, C. F., M.INST.C.E. (Analysis of his Evidence.)

Surveyor in charge of Sheffield Sewage Works, 23481.
Treatment at Sheffield: precipitation and tank followed by contact beds, 23482.
Population of drainage area 400,000, 23483.
Small proportion of storm waters dealt with by separate sewers, 23484.
Infiltration of subsoil water in the older sewers, 23485, 23498.
Water supply 21·23 gallons per head, 23486.
Water is soft, 23487.
Drainage area 23,654 acres; 9,000 acres sewered, 23488.
39,000 water-closets; 54,000 privies or pail-closets, 23489, 23628–30.
Particulars of average dry-weather flow, 23490, 23680–5.
Maximum dry-weather flow 19,400,000 gallons, 23491.
Minimum dry-weather flow 8,600,000 gallons, 23492.
Maximum wet-weather flow 22,000,000 gallons, 23493.
80 storm overflows on the sewers, 23494.
Largest number past last overflow 22,000,000 gallons, 23495.
Annual rainfall 6,432,927,906 gallons, 23496.
Volume of sewage, 1899 to 1904, 23497.
Impossible to say what volume passes overflows, *ib.* 23631–3.
Quantity and schedule of trade effluents, 23499.
Regulations for trade effluents under consideration, 23500.
Interfere with purification both by quality and fluctuation, 23501.
Sewage can scarcely be called strong, 23502.
Strength varies daily and hourly, 23503.
Suspended solids in storm time, 23505.
Large proportion of sewers comparatively new, 23506, 23634–5.
Treatment of sewage in storm time, 23507, 23586, 23700–5.
Drawings of storm overflows, 23508.
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Configuration of the land important in regard to overflows, 23510.
Weir should be fixed but easily regulated, 23511.
Dilutions should depend on size and nature of stream, 23512.
Road water separately treated, 23513, 23843–52.
Should in certain circumstances be purified, 23515.
Cost and advantages of separate and combined systems, 23516.

WIKE, C. F.—*cont.*
Experiments in quiescent and continuous settlement, 23517.
Time necessary to get a good tank liquor, 23518, 23914.
Settlement tanks used in parallel, 23519.
Baffling boards a decided advantage, 23520.
Method of sludging in use, 23521.
Heavy solids removed by catch-pits and screens, 23522.
Farmers will not take the sludge, 23523, 23532,
No chemical poisons in the sludge, 23524, 23533.
No nuisance from settlement tanks, 23525.
Treatment of lime effluent on contact beds a failure, 23527, 23636.
Method of adding lime, 23529.
Sewage remains in tank 45 minutes, 23530, 23706.
No nuisance from chemical precipitation, 23534.
Construction and working of septic tanks, 23535.
Possible to over-septicize the sewage, 23543, 23637–8.
Tanks worked for long periods without sludging, 23544.
Sludge objectionable and removal offensive, 23545.
Suspended solids increase towards end of working, 23546.
Not suitable for storm water sewage, 23547.
Treatment compared with settlement, 23550, 23639–41.
Experimental tank gave rise to complaints, 23552.
Suspended solids should be removed before filtration, 23553–6.
Comparative cost and advantages of the various methods of settlement, 23557.
Construction and working of contact beds, 23558–70, 23644.
Rate of loss of capacity, 23571.
Gaugings of a first and second contact bed, *ib.*
Loss not in proportion to volume treated, 23572,
Material can be washed satisfactorily, 23573, 23642–3, 23881–912.
Best way to maintain capacity, 23574.
No poisons in final effluent, 23575.
First flush from first bed slightly putrescible, 23576.
Beds may be used as streaming storm filters, 23578.
Cost of contact beds, 23579.
No nuisance from contact beds, 23580.
Percolating filters not satisfactory, 23581.
Contact beds are preferable, 23582, 23590.
Method of disposing of sludge, 23587, 23645
Constituents of a good effluent, 23589.
Putrescibility test the most important, 23591.
Single standard very undesirable, 23592.
Central authority, if formed, might discriminate as to standards, 23593.
Automatic working not advisable, 23594.
Average analyses of sewage, etc., 1903–4, pp. 485–519.

WILKINSON, JAMES B., M.D. (Edinburgh), D.P.H., F.C.S. (Analysis of his Evidence.)
In charge of Oldham Sewage Works, 22565.
Population of drainage area about 140,000, 22567.
Drainage system is combined, 22568.
Infiltration of subsoil water about 100,000 gallons a day, 22569, 22582.
Water supply about 23 gallons per head, 22570.
Quality of the water, 22571.
Drainage area about 3,700 acres, 22572.
Number of pails, etc., and water closets, 22573.
Average dry weather flow about 4,500,000 gallons in winter and 2,700,000 in summer, 22574.
Maximum dry weather rate of flow 6,700,000 gallons, 22575.
Minimum dry weather rate of flow 750,000 gallons, 22576.
Maximum wet weather flow at rate of 36,000,000 gallons, 22577.
Description of storm overflows, with plan, 22578, 22598.
Largest amount past last overflow 24,000,000 gallons, 22579.
Annual rainfall about 5,200,000,000 gallons, 22580.
Volume of sewage in 1902, 1,466,128,154 gallons; in 1903, 2,062,406,000 gallons, 22581.
Practically no trade effluent; worst pollution from mill reservoirs, 22583.
Generally insufficient to affect purification, 22585.

WILKINSON, JAMES B.—*cont.*
Suspended matter in sewage, 22586.
Sewage is a strong domestic sewage, 2258
Variation in strength considerable, 22590.
Best measure of strength of sewage, 22591.
No chemical poisons in the sewage, 22593.
Sewage generally neutral or slightly alkaline, 22594.
Suspended solids in storm times, 22595.
Sewers laid 30 or 40 years ago; some deposit in the new intercepting sewer, 22596.
Treatment of sewage in storm times, 22597.
Storm overflows should depend on configuration of land, 22600.
Should be movable, 22601, 22702–5.
Dilutions should depend on relative volumes of stream and sewage, 22602.
Description of the settlement tanks, 22604–8.
Six or eight hours necessary to get good tank liquor, 22606.
Method of sludging tanks, 22609.
Road detritus, ashes, etc., should be removed, 22610.
Farmers use sludge for grass lands, 22611, 22619.
No chemical poisons in the sludge, 22612.
No nuisance from settlement tanks, 22612*.
Sedimentation preferred to chemical precipitation, 22614.
Septic effluent gives better results than either, *ib.*
Most effective way of adding chemicals, 22615–8.
No nuisance from chemical precipitation, 22621.
Construction and working of septic tanks, 22622–39, 22699–701.
Sludge should be drawn off while working, 22629.
Septic tank sludge hard to press, should be dried, 22630.
Suspended solids increase towards end of working, 22631.
First portion of storm water must be treated, 22632.
Causes no harm to septic tanks if amount not too great, *ib.*
Septic tank effluent gives better filtrate than settled or precipitated sewage, 22636.
No nuisance from septic tanks, 22639.
Suspended solids should be removed before filtration, 22640.
Advantages of various methods of settlement, 22641.
Construction and working of contact beds, 22642–93.
Rate of loss of capacity, 22655, 22668–86.
First flush taken by itself is putrescible, 22661. 22706–8.
Beds may be used in times of storm as streaming filters, 22662.
Cost from £1,000 to £2,000 per acre, 22663.
No nuisance from contact beds, 22664.
Effluent discharged into river, 22695–8.

WILKINSON, J. P. (Analysis of his Evidence.)
Engineer of Manchester Sewage Works, 24233.
Population of Manchester drainage area 575,500, 24234.
System almost entirely combined, 24235.
Daily infiltration of subsoil water 6,000,000 gallons, 24236.
Water supply 29 gallons per head, 24237.
Water is soft, 24238.
Drainage area 11,800 acres, 24239.
62½ per cent. use pails and middens; 37½ use water closets, 24240, 24298–300.
Average dry weather flow in winter 26,481,000, in summer 25,311,000 gallons, 24241.
Maximum dry weather flow 37,236,000 gallons, 24242.
Minimum dry weather rate of flow 18,644,000 gallons, 24243.
Maximum wet weather rate of flow 222,625,000 gallons, 24244.
215 storm overflows designed to operate at 5 dilutions, 24245, 24301.
Rates observed in typical instances, *ib.*
Largest number past last overflow, 163,624,000 gallons, 24246.
Annual rainfall 8,432,943,750 gallons, 24247.
Volume of sewage 12,000 to 13,000 million gallons per annum, 24248, 24302–5.
Amount passing overflows cannot be stated, *ib.*
Infiltration varies with season and weather, 24249.

WILKINSON, J. P.—*cont.*
Volume and description of trade effluents, 24250.
Some of the older sewers have settled, causing deposit, 24251.
Treatment of sewage in storm times, 24252, 24306, 24335–40, 24371–406.
Standard form of overflow not possible, 24254.
Operation of overflow should be settled for each individual case, 24255, 24341.
Overflows should be fixed as a rule, 24256.
Dilutions may depend on nature of stream, 24257.
Circumstances determining operation of overflows, *ib.*
Early flush of road water should be purified, 24259.
Comparative cost and advantages of separate and combined systems, 24260, 24307–17.
Construction and working of septic tanks, 24261–77, 24411.
Sludge should be removed periodically, 24268, 24407.
Method of removal and disposal of sludge, 24269, 24408–31.
Suspended solids in tank liquors, 24270–3.
One dilution with rain may go through tank, 24272.
Reasonable fluctuation in level not prejudicial, 24275.
No nuisance except when sludging tanks, 24277.
Method of removal of suspended solids, 24279–80, 24318–22.
Comparative cost and advantages, with and without chemicals, of quiescent and continuous settlement, 24281, 24323–32, 24344–70.
Construction and working of contact beds, 24282–7.
Crude sewage should not be put on beds, 24288.
Observations on automatic gear, 24291, 24333–4.
Causes of loss of capacity, 24292.
Best method of maintaining capacity, 24294.
Cost of beds and volume treated, 24295.
Practically no nuisance from contact beds, 24296.
Approximate estimate of amount passing storm overflows, 24302–5.
Quite practicable to burn sludge cake, 24414–22.
Preferable to put it on land, 24423–6.
Suitable land would take more than 20 tons per acre, 24431.

WILLCOX, J. EDWARD, M.INST.C.E., AND HUGH P. RAIKES, A.M.I.C.E. (Analysis of their Evidence.)
Sewage treatment at Hanley, 25993–4.
Population of drainage area 60,000, 25995 (1).
One quarter drained on separate system, *ib.*, (2), 26022.
Little infiltration of subsoil water, 25995 (3), 26000.
Water supply and analysis of water, 25995 (4).
Water moderately soft, *ib.* (5).
Whole area of 1,800 acres sewered, *ib.* (6).
Eighty-five per cent. water-closets; remainder middens or pails, *ib.* (7).
Average dry weather flow 3,600,000 to 4,000,000 gallons, *ib.* (8), 26287–94.
Storm overflows now being constructed, 25996.
Largest daily flow 14,000,000 gallons, 25997, 26144–5.
Rainfall twenty-three inches, 25998.
Information as to total sewage not available, 25999, 26147.
About 1,250,000 gallons trade effluent daily, 26001.
No rules as to trade effluent, 26002.
Clay in trade waste called "slip" increases sludge, 26003, 26257–8.
Average amount of suspended matter in sewage, 26004.
Physical character of the solids, 26005.
Average analysis of sewage, 1903–4, 26006, 26307.
Sewage a little below average strength, 26007–8, 26148, 26256.
Best measure of strength of sewage, 26009, 26148.
No chemical poisons in sewage, 26011.
Sewage always alkaline, 26012.
Suspended solids increased in times of storm, 26013.
Sewers laid about 1870 with good gradients, 26014.
Character of liquid sewage in storm times, 26015.
Treatment of sewage in storm times, 26016, 26148–59.
Shape and size of storm overflows, 26017.
Standard overflow not desirable, 26018, 26160–3.
Not practicable to make overflow depend on configuration of surface of land, 26019, 26163–7.

WILLCOX, J. E., AND HUGH P. RAIKES—*cont.*
Overflows should be capable of adjustment, 26020, 26168.
Dilutions may depend on size and nature of stream, 26021.
Overflow should not operate under three volumes, 26021, 26147, 26295–300.
Surface water from paved spaces should be purified, 26025.
Comparative cost and advantages of separate and combined systems of sewers, 26026, 26308.
Sewage settled by continuous settlement, 26027.
Analysis of crude sewage and detritus tank effluent, 26027, 26309–11.
Two-thirds of suspended matter removed in one hour, 26028, 26259–64.
Seldom possible to obtain good liquor by settlement alone, 26029.
Tanks should be used in parallel where slow velocity required, 26030.
No advantage in baffling boards or walls, 26031.
Sludge dealt with in filter presses; no nuisance, 26032.
Settling tanks only a preliminary to precipitation, 26033.
Sludge has practically no manurial value, 26034.
No chemical poisons in it, 26035.
No nuisance from settlement tanks, 23036.
Tendency of chemically treated liquor to clog land filters, 26038, 26312–3.
Septic tanks give results equal to chemical precipitation, 26039.
Chemicals should be thoroughly mixed, 26040.
Analysis of effluent from precipitation tank, 26041.
Flocculent organic matter suspended, 26042.
Lime required in treatment of sludge, 26043.
No manurial value beyond that of the lime, 26044.
Contains no chemical poisons, 26045.
No nuisance from chemical precipitation tanks, 26046.
Construction and working of septic tanks, 26048–74.
Stagnant sewage becomes over-septicised, 26055.
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